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THE CHAOS IN MORAL TRAINING.

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IN teaching undergraduates in the subject of ethics, I have been impressed with the need of getting the discussion as near as possible to what is going on in the minds of students themselves. Although ethics is the most practical of the philosophic studies, none lends itself more readily to merely technical statement and formal discussion. It is easy to forget that we are discussing the actual behavior, motives, and conduct of men, and substitute for that a discussion of Kant's or Mill's or Spencer's theory of ethics. It seems to me especially advisable to get in some contact with the practical, and accordingly largely unconscious, theory of moral ends and motives which actually controls thinking upon moral subjects. One is, however, considerably embarrassed in attempting this. As any one knows who has much to do with the young, their conscious thoughts in these matters, or at least their statements, are not fresher, but more conventional, than those of their elders. They are apt to desire to say the edifying thing, and the thing which they feel is expected of them, rather than express their own inner feelings. Moreover, some points have been so much discussed that any direct questioning upon them is apt to bring forth remnants of controversies that have been heard or read, secondhand opinions, an argumentative taking of sides, rather than to evoke the spontaneous and native attitude. Among other devices for eliminating or at least reducing these disturbing factors the following method was hit upon: To ask each student to state some typical early moral experience of his own, relating, say, to obedience, honesty, and truthfulness, and the impression

left by the outcome upon his own mind, especially the impression as to the reason for the virtue in question. The answers brought out a considerable mass of material, incidentally as well as directly. Some of this seems to me to have value beyond the immediate pedagogical occasion which called it forth, as furnishing a fairly representative sample * of the motives instilled by existing methods of moral training, and the impressions which these methods leave behind.

Nine tenths of the answers may be classified under one of the following heads: The impression left by the mode of treatment was that the motive for right doing is (1) found in the consequences of the act; (2) fear of being punished; (3) simply because it is right; (4) because right doing pleases the parent, while wrongdoing displeases; (5) the religious motive. In number the religious motive predominates; next to that comes fear of punishment. In many cases, of course, several of these reasons were inculcated.

1. The regard for consequences as a reason for morality takes the form of regard either for external consequences or for intrinsic reactions—that is to say, upon the character of the agent or upon those about him. A number seem to have learned the value of obedience by observation of disagreeable results proceeding from its opposite. For example, one child was told not to take off her shoes and stockings; she disobeyed, and had croup in the night—whence, she remarks, she derived the idea that others knew more than she, and that disobedience was dangerous. Another girl was told not to wear a lawn dress to a picnic; she disobeyed, but a rain storm came up and faded it out. "From this and other similar experiences I deduced the idea that obedience was wise. Yet this was with the reservation that obedience was to be tempered with discretion, as I observed that in some instances acting upon my own judgment was justified by the outcome."

When we come to the moral motive as determined by the intrinsic results of the act, we are obviously approaching the question, so mooted upon its theoretical side, of intuitionalism *versus* empiricism. Nothing was said upon this point in giving out the questions; the students may fairly be presumed to have been unconscious of any such bearing in their answers, and so these may be taken as fairly free from any bias. No one reply indicates any distinct recognition of right or wrong prior to the commission of

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* The class numbered over one hundred. About ninety replied. About twenty of the answers were put aside, as indulging in general statements, or as bearing the stamp of artificiality. The remaining answers represent Central Western States, particularly the States of Michigan, Illinois, and Indiana. Pretty much all grades of homes are represented, and at least three lines of descent beside native American.

some particular act.* After acting, a number of persons note the fact that they became so uncomfortable that they either owned up or resolved not to do that sort of thing again. This experience, however, is noted only in the case of a lie told or acted. Several expressly state that obedience and honesty (as a regard for the property of others) appeared quite artificial, their need being seen only after considerable instruction and some rather crucial experiences. Obedience, in many cases, seemed quite arbitrary—"necessary for children," as one puts it, "but not for grown people"; or, as another notes, "till he got big enough so he wouldn't have to mind"; while a third states that obedience, as such, was always accompanied with a certain resentment and a desire to have the positions reversed, so that he could do the commanding. As for honesty, one says that it always seemed to him that anything he wanted to use belonged to him; another, that any pretty thing which she admired was her own. One child notes that she saved up the pennies her father had given her to take to Sunday school, and bought a valentine with them, which she gave to him, to surprise him. The father threw this into the fire first, and then punished her, taking it for granted that she knew she was doing wrong.† Not even after that, however, did she feel it was wrong, but rather felt indignant and humiliated that her father had treated her gift in such a way. Another child could see no wrong in taking the pennies from a bank which she and her sister had in common. The following instance is worth quoting in full: "Before I was four, I remember several instances in which I saw moral delinquencies in others, which I wished to punish or did punish, but none in myself. As to honesty, I claimed all the eggs laid in the neighborhood as coming from my own pullet. After being convinced of the physical impossibility of this, it was a long time before I would believe that everything I laid hands on was not mine. I was once driven off from a field where I was picking berries; this made a great impression upon me, and led to questions regarding the rights of others to be so exclusive. The effectual appeal always lay in being led to put myself in the place of others." A number note that there was great difficulty in appreciating that a fence could institute a moral barrier between mine and thine. But as regards lying, a few report having been

* This *may* be due, of course, to the way in which the question was put.

† A sense of injustice seems to have been the first distinctly moral feeling aroused in many. This, not on account of the wrong which the child did others, but of wrong suffered in being punished for something which seemed perfectly innocent to the child. One of the distinct painful impressions left on my own mind by the papers is the comparative frequency with which parents assume that an act is consciously wrong and punish it as such, when in the child's mind the act is simply psychological—based, I mean, upon ideas and emotions which, under the circumstances, are natural.

made thoroughly uncomfortable by its after effects in their own emotions. The following story, trivial in itself, is not trivial in meaning: "Once, when I had two apples, I wished to give one to my playmate; I knew she would expect the best one, which I also wished for myself, so I held out the best side of the poorer one and made her think that was the better of the two. Her belief that I had really given her the best took away all the sweetness from my own apple, and I decided that straightforwardness was better." This instance, as well as others pointing in the same direction, so far as they would justify any conclusion, fall in line with the case reported by Professor James relative to the experience of a deaf-mute. This boy had stolen ten dollars, thinking it a smaller sum, having previously stolen many small amounts with no compunctions of conscience. In this case, the reaction into himself was, so to speak, so massive and bulky that he became thoroughly uncomfortable and ashamed; was brought spontaneously to recognizing its badness, and kept from stealing money in the future. This genuine meaning of the innate theory of conscience seems accordingly, to Professor James, to mean that any act, if it can be experienced with adequate detail and fullness, "with all that it comports," will manifest its intrinsic quality.*

2. An astonishingly large number record that they got their first distinct moral impressions through punishment, and of these a considerable fraction got the idea that the chief reason for doing right was to avoid punishment in the future. This division runs into that dealing with the religious motive, as sometimes the fear was of punishment from parent, sometimes from God; it also runs into the fourth head to be considered, practically if not logically, for a number record that the motive appealed to by their father was fear of punishment, while that of their mother was love of her, and grief caused by wrongdoing.

A few samples tell, in different language, the almost uniform tale of the outcome of the appeal to force. "I rebelled with feelings of hatred and of desire for revenge. It seemed to me unjust, imposed by sheer force, not reason." One tells the story of being coaxed by older boys to steal some tobacco from his father. "I was caught and given a whipping, no questions being asked and no explanation given. The result was certainly a fear of punishment in the future, but no moral impression. I thought my father whipped me because he wanted the tobacco himself, and so objected to my having any of it." Another reports that the impression left by punishment was a mixture of a feeling of personal indignity suffered—a feeling so strong as to blot out the original

* Philosophic Review, vol. i, p. 674. I can but think, however, that Professor James is very charitable in ascribing to the ordinary intuitionalist any such reasonable view.

offense—and a belief that she was punished for being detected. Another thought she was punished because her father was the stronger of the two; another, that fear of harm to self induced people to do right things; another tells that he longed for the age of independence to arrive so that he might retaliate. One upon whom fear of punishment from God was freely impressed formed the idea that if he could put off death long enough, lying was the best way out of some things. One child (five years old) went in the front part of the house after she had been forbidden, and, falling, hurt herself. She was told that this was a punishment from God; whence she drew the not illogical conclusion that God was a tyrant, but that it was possible to outwit him by being more careful next time, and not falling down. One peculiarity of the method of inducing morality by creating fear is that some parents, in order to prevent lying, deem it advisable to lie themselves; e. g., talk about cutting off the end of the boy's tongue or making him leave home, etc. But there is hardly any need of multiplying incidents; all the reports re-enforce the lesson which moralists of pretty much all schools have agreed in teaching—that the appeal to fear as such is morally harmful. Of course, there are a number of cases where good results are said to have come from punishment, but in such cases the punishment was incidental, not the one important thing; it was the emphasis added to an explanation.

3. Some report that they were instructed to do right "because it is right," either as the sole reason or in connection with other motives, such as harm to one's character, or displeasing God or parents. A little more than one tenth of the persons report this as a leading motive instilled. Most simply mention the fact, with no comment as to the impression made upon them. One remembers displeasing her mother (after she had been told that she must do right because it was right) by asking why she must do what was right rather than what was wrong. On the whole, she was confused, and the basis of morality seemed to be arbitrary authority.

4. Such answers as the following are exceedingly common: "I saw by mother's face that I had grieved her"; "was made to feel that I had shocked and pained my parents"; "the motive appealed to was giving pain to my parents, who loved me"; "I felt ashamed when I found I had grieved my father"; "was made to feel sorry when my parents were made unhappy by what I did," etc. There is a paucity of information about the attitude toward morality left by this mode of treatment. The following, indeed, is the only comment made in any of the reports: "Upon disobeying my mother, I was told that I was naughty and bad, and that she would not love me unless I was sorry and promised not to dis-

obey again. This impressed me with the *necessity* of obeying, but I did not see then, and can not now, any *reason* for it."

5. We come now to the religious motive as the ground for right doing. There are different kinds of answers here—appeals to fear and love, to Bible teachings and Bible warnings, to terror of an avenging God, and to the wounded affection of a personal friend and Saviour; sometimes one, and sometimes a mixture of all. Certain of the practical ones among the parents used, indeed, not only all these appeals, but pretty much all the foregoing mentioned as well, evidently on the principle that it is not possible to use too many inducements toward morality, and that if one fails, another may hold. I shall give one or two typical quotations illustrating each method. First, of fear: "My mother told me, 'You must tell the truth, for God knows all about it, for he is continually watching you, and I certainly shall find out all about it.' This caused great fear; we thought of God as a powerful avenger, and also believed that he communicated with our parents about our faults." Three or four mention that the story of Ananias and Sapphira was used with considerable effect. Second, of Biblical authority: "I was taught that the Bible said that these things were right and wrong, and that it must be so. I can not remember a time when I did not think that it was wrong to break any of the ten commandments, because they had been given by God in the Bible." "When I asked the reason why I should not do certain things, I was told that it was because they were forbidden in the Bible." Third, of love: "I was taught that Jesus looked upon me, just as my parents did; that he was pleased when I did right, and grieved when I did wrong, and that he had done so much for me that I ought to be sorry to grieve him." "I was taught that wrong acts grieved our Lord, and that he knew about them even if no one else did; also that he was pleased when I did any little act of kindness to any one." Fourth, mixed cases: "I was brought up in a distinctly Christian home. I was made to feel that certain things were right and their opposites wrong; was taught that there is a God who sees and knows everything that I do; that he looked upon disobedience with an eye of displeasure; the Bible was taught from early infancy as a text-book of morals; was made to feel that not only would punishment result from wrongdoing, but that both God and my parents were hurt by my wrongdoing. The impression left on my mind was that certain things were right and that God was the standard; at first fear, awe, and reverence were induced, with occasional feelings of rebellion; the general effect was to awaken respect for the right qualities, and to make me consider the right and wrong of things in my own consciousness." "After the first lie which I remember, I was not

punished, but was given a lecture on the words in the Revelation, 'Without are . . . whosoever loveth and maketh a lie.' I was made to see that the habit would grow and dishonor me in the sight of God and man, and left with the promise of a good whipping if I ever told another. In general, I remember that I was taught that my faults had the peculiarity of increasing at an astonishing rate; that I was a very naughty child, and that every wrong act grieved a heavenly Father who loved me and who was ever present to see both the good and the bad." "After lying I was told that I got no good from it; that teachers and friends disliked such persons; that my honest playmates would look down on me; that God was grieved with me. The room was filled with the splendor of the setting sun, and it seemed to me that God must be up there looking at me and seeing what a naughty girl I was. Then I was told that God would forgive me if only I confessed, and that in the future he would help me to be good if only I tried."

I am not afraid that any one will despise these incidents as trivial. It is easy, indeed, to recall our own childhood, to look out at what is now around us, and say that there is nothing new here; that all this is commonplace and just what any one would expect. Precisely; and in that consists its value. It all simply brings out the most familiar kind of facts, but still facts to which we shut our eyes, or else ordinarily dismiss as of no particular importance, while in reality they present considerations which are of deeper import than any other one thing which can engage attention. Every one will admit without dispute that the question of the moral attitude and tendencies induced in youth by the motives for conduct habitually brought to bear is the ultimate question in all education whatever—will admit it with a readiness and cheerfulness which imply that any one who even raises the question has a taste for moral truisms. Yet, as matter of fact, moral education is the most haphazard of all things; it is assumed that the knowledge of the right reasons to be instilled and knowledge of the methods to be used in instilling these reasons "come by nature," as reading and writing came to Dogberry. There is, if I mistake not, a disposition to resent as intrusion any discussion of the subject which goes beyond general platitudes into the wisdom of the motives and methods actually used. Yet I do not see how any successful training of children as to their conduct is possible unless the parents are first educated themselves as to what right conduct is, and what methods are fit for bringing it about. I do not see how that is to be accomplished without a free treatment of present aims and methods.

The first thing which strikes one's attention in these answers is the great gap existing at present between theory and practice.

Either prevailing theory is egregiously wrong, or else much of present practice, measured by that theory, may be fairly termed barbarous in its complete disregard of scientific principle. If there is one thing in theory upon which all schools are agreed, it is that conduct is not moral except as its motive is pure—except, that is, as free from reference to personal fear of punishment and hope of reward. The intuitionalist insists that duty must be done for duty's sake; the empiricist, that while consequences make the moral criterion, yet the agent is truly moralized only in so far as his motive is regard for the consequences which follow intrinsically from the act itself. And yet the main motive actually appealed to is the desire to avoid either actual punishment, whether from God or from one's parent, or else the reflex into one's self of their displeasure in the way of being grieved or hurt. The last motive appealed to, it would seem, is that connected with the act itself. Enlightenment as to the true nature of the act performed, irrespective of the source of its imposition, irrespective of the favor or disfavor which the act will arouse from others (save, of course, in so far as that disfavor or favor is, through the social structure, one of the *intrinsic constituents* of the act) and the development of interest in that act for its own sake, seem to be the last things aimed at.* It is commonly said, I know, that a child can not understand the moral bearing of his acts, and that therefore rather arbitrary and external motives must be appealed to. Of this, I would say two things: First, it is true that the child can not see in the act all that an adult sees in it. There is not the slightest reason why he should. If he did, it would be an entirely different act, an act having different conditions, a different aim, and a different value. The question is whether the child can be made to see the reason why *he* should perform the act, not why some other older person should perform it. Limiting the question in this way, it loses, I think, a large part of its force. As for what remains, it may still be said that the ideal is to appeal to the child's own intelligence and interest *as much as possible.* One of the strongest impressions made upon me by the papers is the natural strong interest of children in moral questions—not, indeed, as consciously moral, but as questions of what to do and

* I hope I shall not be understood here as arguing for the principle of doing right because it is right. In the first place, the phrase is very ambiguous, meaning either doing the act for the sake of something right, in the abstract or at large, a right whose connection with the particular act is not seen; or else doing the act for its own sake, for the meaning which the act itself has for the agent—a principle which is the extreme opposite of the other sense. But, in the second place, I am desirous to state the matter in terms upon which all schools are agreed; and I understand that (however differently they may phrase it) all schools are agreed that an act has really moral worth only when the agent does it because of what *he* sees and feels in it.

what not to do. We do not have to take any position regarding the intuitive character of moral distinctions or the *a priori* character of moral laws to be sure that a child is intensely interested in everything that concerns himself, and that what he does and how other people react to it is a very intimate part of himself. To decline to show the child the meaning of his acts, to hold that his desire to know their reasons (that is, their meaning) is a sign of depravity, is to insult his intelligence and deaden his spontaneous interest in the whys and wherefores of life—an interest which is the parent's strongest *natural* ally in moral training.

Secondly, in and so far as the child can not see the meaning and value of his acts and value them for himself, it becomes absurd to insist upon questions of morality in connection with them. Make the widest possible allowance for the necessity that a child perform acts, the bearing of which he can not realize for himself, and the contradiction in the present method is only emphasized as long as parents impress upon the children strictly moral considerations in connection with such acts. Surely, if morality means (as all moralists are agreed) not simply doing certain acts, but doing them with certain motives and disposition, rational training would emphasize the moral features of acts only when it is possible for the child to appreciate something of their meaning, and in other cases simply manage somehow to get the acts done without saying anything about questions of right and wrong. To continue the present method of holding, on one side, that a child is so irrational that he can not see for himself the significance of his conduct, while, on the other, with regard to these self-same acts, the child is punished as a *moral* delinquent, and has urged upon him, on *moral* grounds, the necessity for doing them, is the height of theoretical absurdity and of practical confusion. Present methods seem to take both the intuitive and utilitarian positions in their extreme forms, and then attempt the combination of both. It is virtually assumed that prior to instruction the child knows well enough what he should and should not do; that his acts have a conscious moral quality from the first; it is also assumed, to a large extent, that only by appeal to external punishments and rewards can the child be got to see any reason for doing the right and avoiding the wrong. Now these two propositions are so related that they can not possibly both be true, while both may be false—and *are* both false unless all contemporaneous tendencies in ethics are in a wrong direction.*

* There is one basis upon which both views may be logically held—total depravity. It may then be assumed that the child knows the right in advance, but can be got to *do* it only through punishment.

The gap between theory and practice comes out also in the great reliance placed upon religious motives in the moral life. It is not necessary to enter into controversial questions here. The fact is enough that contemporary moralists, almost without exception and including all schools, hold that the reasons and duties of the moral life either lie within itself, or at least may be stated by themselves without direct reference to supernatural considerations. In running over the names of moral theorists of the present day, of all schools, I can think of but two exceptions to this statement. Sidgwick holds that it *may* be impossible to get a *final* statement of morals without postulating a supreme moral Being and Ruler, while Martineau holds that obligation is derived from such a Being. But even Martineau holds that the *facts* of obligation may be found directly in human nature; that it is only when we demand a philosophical explanation of its *nature* that we bring in the reference to God. Either, then, theory is working in a very unpractical direction, or else much of practice is going on in very anti-scientific fashion. A readjustment is demanded.

This brings me to my final point. An influential movement of the present times (I refer to the ethical culture movement) holds, as I understand it, that it is possible to separate the whole matter of the moral education of children and adults from theoretical considerations. With their contention that education can be (must be, I should say) separated from dogmatic theories I am heartily at one; but as, after all, a dogmatic theory is a contradiction in terms, the question is, whether such an emancipation can be effected without a positive theory of the moral life. It is a critical and practical question with every teacher and parent: What reasons shall I present to my child for doing this right act? What motives in him shall I appeal to in order that he may realize for himself that it is right? What interests in him shall I endeavor to evoke in order to create an habitual disposition in this right direction? I fail utterly to see how these questions can be even approximately answered without some sort of a working theory. To give a reason to a child, to suggest to him a motive—I care not what—for doing the right thing, is to have and use a moral theory. To point out its consequences to himself in the ways of pains and pleasures; to point out its reaction into his own habits and character; to show him how it affects the welfare of others; to point out what strained and abnormal relations it sets up between him and others, and the reaction of these relations upon his own happiness and future actions—to point to any of these things with a view to instilling moral judgment and disposition is to appeal to a theory of the moral life. To suppose that the appeal to do a thing simply because it is right does *not* involve such a theory; to suppose that the practical value of this

appeal must not itself be submitted to investigation and statement—to theory—strikes me as decidedly naïve.

Here as elsewhere our greatest need is to make our theories submit to the test of practice, to experimental verification, and, at the same time, make our practice scientific—make it the embodiment of the most reasonable ideas we can reach. The ultimate test of the efficacy of any movement or method is the equal and continuous hold which it keeps upon both sides of this truth.

A FAMILY OF WATER KINGS.

By Prof. CLARENCE M. WEED.

THERE is, perhaps, no way in which one can obtain a more vivid idea of the intensity of the struggle for existence among organic beings than by the study of the inhabitants of a fresh-water pond of long standing. Every inch of space in such a situation is teeming with life, both animal and vegetable, and the chief delight of most of the animals present is to wage a ceaseless warfare upon their weaker fellows. It is an aquatic rendition of Edwin Arnold's aërial drama:

> " . . . Then marked he, too,
> How lizard fed on ant, and snake on him,
> And kite on both; and how the fish-hawk robbed
> The fish-tiger of that which it had seized;
> The shrike chasing the bulbul, which did hunt
> The jeweled butterflies; till everywhere
> Each slew a slayer and in turn was slain,
> Life living upon death. So the fair show
> Veiled one vast, savage, grim conspiracy
> Of mutual murder, from the worm to man,
> Who himself kills his fellow."

The largest insects occurring in our fresh-water ponds are the giant water bugs—a family of peculiar creatures, armed with immense front legs fitted for grasping and clasping their victims, and a piercing, dagger-like beak which serves both to strike the prey and as a sucking tube to extract its juices, and which also appears to be provided with poison glands which make more sure the effect of every thrust.

Three species of these bugs occur in the Northern United States. Two of them are very large and closely resemble each other; the third is much smaller, less than half the size of the others. The commoner of the larger ones in the more northern States is represented natural size in Fig. 1. It is called by entomologists *Belostoma americana*, or the American belostoma. It is

brown in color, with leathery wings overlapping each other on its back; thick legs, along the sides of which are fringes for swimming; and a flat, boat-shaped body which offers little resistance to the water.

The eggs of the American belostoma are deposited on pieces of wood or reeds along the margins of ponds, apparently where they will be wet but not directly in the water. They are laid in clusters of from forty to sixty or more in each. The eggs themselves are about one fifth of an inch long, oblong-ovate in form, with the general color brown spotted with black; they are lighter colored below than above, and there is a whitish crescent near the top with a distinct black spot in its apex. This crescent indicates the margins of a little cap which comes off when the young bugs hatch.

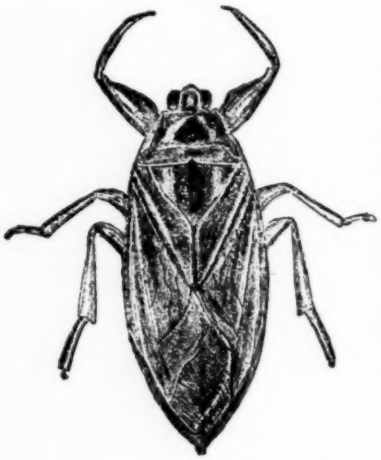


FIG. 1.—AMERICAN BELOSTOMA.

Little seems to be known concerning the early history of these bugs. They probably crawl into the water soon after hatching, and live upon such aquatic insects as they are able to catch. I do not know just how fast they grow, but presume they become full grown in a year. During the earlier period of their existence they have no wings; they are then in what the naturalists call the nymph state. Their appearance just before they become adult is represented in Fig. 2. It will be seen that they have no wings, but otherwise they very much resemble the full-grown bugs. Finally, the skin splits open along the middle of the back, and the insect crawls out of its old skin clothed in a new one which is provided with wings. It now for the first time can leave the pond where it has developed, and fly away to other bodies of water.

FIG. 2.—LAST STAGE OF NYMPH.

If the front leg of a full-grown American belostoma be examined carefully, there will be found on the front margin of the long joint nearest the body a longitudinal groove for the reception of the next joint. By this character the present species can always be distinguished from the other one, in which there is no groove. This latter insect is called *Belostoma griseus*. It is usu-

ally a little larger and darker colored than its American cousin, and apparently is more common southward than at the North. The life histories of the two species, so far as we know them, appear to be very similar. The eggs of the southern form are laid in masses on sticks or other rubbish at the margins of ponds. The general color of recently laid specimens is greenish brown, with longitudinal stripes of darker brown, and a faint indication of a light crescent near the top. Their bases are glued to each other and to the stick on which they are deposited by a sort of mucilage. An idea of the appearance of these eggs may be obtained from Fig. 3.

FIG. 3.—EGGS.

In South America a still larger species is found; it is called *Belostoma grande,* or the great belostoma. Still other species occur in Central America and Cuba, China and India, Egypt and Africa, but none are found in northern Europe.

Wherever these bugs appear they are formidable enemies of small fishes, frogs, and other aquatic animals. Of the *Belostoma griseus,* Prof. Uhler writes: "Developing in the quiet pools, secreting itself beneath stones or rubbish, it watches the approach of a mud-minnow, frog, or other small-sized tenant of the water, when it darts with sudden rapidity upon its unprepared victim, grasps the creature with its strong, clasping fore legs, plunges its deadly beak deep into the flesh, and proceeds with the utmost coolness leisurely to suck its blood. A copious supply of saliva is poured into the wound, and no doubt aids in producing the paralysis which so speedily follows its puncture in small creatures." In the breeding ponds of the Massachusetts Fish Commissioners these bugs destroyed so many young fish a few years ago that the authorities had to take special pains to catch and kill them.

In many localities these insects have lately received the popular name electric-light bugs, because they fly so freely to electric lights. This indicates that in going from pond to pond they are nocturnal.

FIG. 4.—RIVER ZAITHA.

There is another species belonging to this family which is common throughout most of the United States. It is less than half the size of those we have been discussing, and is called by entomologists *Zaitha fluminea,* or the river zaitha; and is also known as the lesser water bug. It is a brown insect of the size and shape shown in Fig. 4. Its legs are provided with fringes for swimming, and it has a slender, sharp-pointed beak. As one would expect, it feeds on smaller animals than do the belostomas. A few years ago I dredged a number of these bugs out of an Ohio pond,

together with a great quantity of other forms of pond life, and placed them all in glass aquaria to study their feeding habits. The bugs seemed to feed most voraciously upon the larvæ or nymphs of dragon flies. These were captured continually, and their juices greedily sucked out. The next most abundant victim was the common undulating backswimmer (*Notonecta undulata*) shown in Fig. 5. In one aquarium, in which a large amount of pond material, including half a dozen zaithas, had been placed, four of the latter were in sight at one time, each with one of these backswimmers grasped in its front legs and the beak inserted in the body.

FIG. 5.—UNDULATING BACKSWIMMER.

Small fresh-water snails occasionally contribute to the diet of this insatiable creature, and young mayflies are also commonly eaten. Flying insects which fall upon the surface of the water are sometimes caught and killed.

The giant water bugs are typical examples of the true bugs. They belong to the group called by naturalists *Heteroptera*, the members of which are characterized by having two pairs of wings, the front pair being thickened at the base and thin at the tip, and mouth parts fitted for sucking rather than for biting. During their development they do not undergo so complete a series of changes as do the caterpillars, which transform into butterflies, but grow more like the grasshoppers, the young resembling the adults in general appearance but having no wings. These bugs can be dipped out of ponds and ditches almost anywhere by means of a net, and are easily kept in aquariums, where they form interesting objects for study.

ILLUSTRATING, in one of his juvenile lectures, the liquefaction and solidification of gases, Prof. Dewar said that ether is evaporated to produce, by abstraction of heat from the gas, solid carbonic acid, which, though a white substance like snow, is boiling at 80° C. below zero. If the pressure is reduced by the air-pump, it boils at a lower temperature, and —110° C. may thus be reached. This is sufficient to liquefy nitrous oxide, which boils at —90° C.; and liquid nitrous oxide under the air-pump produces cold enough to liquefy ethylene, which boils at —100° C. The last stage is to liquefy air under pressure by the cold made by evaporating ethylene. In practice all these stages are not used, but they illustrate the gradational method which must be employed. The lecture was illustrated by liquid air being handed round in a flask inclosed in a vacuum jacket; though at a temperature of —180° C., it was boiling gently away. An idea was given of the difference between its temperature and that of the room by dropping it on a cold metal plate, when it assumed the spheroidal state like water on hot iron.

HUMAN AGGREGATION AND CRIME.

By M. G. TARDE.

UNTIL our own days, through that crisis of individualism which has prevailed since the last century, crime has been regarded as the most essentially individual thing in the world; and the notion of what might be called undivided crime was lost among criminologists, as was that also of collective sin among theologians. Whenever the attempts of conspirators or the exploits of a band of robbers forced the recognition of the existence of crimes committed collectively, the criminal nebulosity was promptly resolved into distinct individual offenses of which it was regarded as only the sum. But now the sociological or socialistic reaction against this great egocentric illusion is turning attention toward the social side of acts which are mistakenly attributed to the individual. Hence curious inquiry has been directed to the criminality of sects—concerning which nothing is more profound than M. Taine's labors on the psychology of the Jacobins—and, more recently, to the criminality of mobs. These are different species of the same genus; the criminality of the group; and the study of them together may be useful and opportune.

The difficulty is not to find collective crimes, but to discover crimes which are not collective, which do not involve in some degree the complicity of the surrounding. So much is this so that we may well ask whether there are any crimes really individual, the same as we doubt whether there are any works of genius that are not a collective result. Analyze the mental state of the most vicious and most isolated malefactor, at the moment of his deed; or that of the most enthusiastic inventor at the hour of his discovery; and having subtracted from it all in the make-up of his feverish condition which comes from education, companionship, apprenticeship, and the accidents of life—what is left? Very little; yet something, perhaps something essential, which does not need to be isolated to be itself.

Nevertheless, it is permissible to denominate individual crimes any acts performed by a single person under the operation of vague, distant, and confused influences of some indefinite and indeterminate other one; and we may reserve the epithet collective for acts brought about by the immediate and direct collaboration of a limited and precise member of coexecutants.

There are, indeed, in this sense, individual acts of genius; or, rather, there is the quality of individuality only in case of genius. For, it is remarkable that while morally, collectivities are susceptible of the two contrary excesses of extreme criminality and ex-

treme heroism, they are not so intellectually; and while they may descend to depths of folly or imbecility impossible to the individual taken by himself, elevation to the supreme display of intelligence and imagination is interdicted to them. They can, morally, fall very low or rise very high; but intellectually they can only fall very low. While there are collective crimes, of which the individual alone would be incapable—assassinations and pillages by armed bands, revolutionary fires, epidemics of venality, etc.—there are also collective achievements of heroism in which the individual rises above himself—charges of the legendary six hundred, patriotic revolts, epidemics of martyrdom, etc. But there are no collective acts of genius that can be contrasted with these. What discovery, invention, or real initiative within historical times has been due to that impersonal being, the public? Does one say revolutions? Not they; what revolutions have accomplished in pure destruction, the public may claim partly at least; but what have they founded and introduced that was novel that was not conceived and thought out before them or after them by superior men like Luther or Napoleon? Can any one cite an army, however well constituted, from which an admirable or even passable plan of campaign has sprung? Or even a council of war, which for the conception—I will not say the discussion—of a military manœuvre was worth the brain of the most ordinary general in chief? Was ever an immortal work in art, a painting, a sculpture, an architectural design, or an epic poem, imagined and wrought out by the collective inspiration of ten or a hundred poets or artists? All that is of genius is individual, even in crime.

To what is this signal contrast due? Why is the grand display of intelligence refused to social groups, while a large and strong display of will and even of virtue is within their reach? It is because the act of most heroic virtue is a very simple matter in itself, and differs from the act of ordinary morality only in degree. The power of unison in human assemblages, where emotions and opinions re-enforce one another rapidly by their multiple contact, is surely irresistible. But the work of genius or of talent is always complicated and differs in nature—not in degree only—from an act of ordinary intelligence. The question in a regular process is not, as in this, one of perceiving and recollecting at random, but of dealing with known perceptions and images in new combinations. At first sight it seems that ten, a hundred, or a thousand heads together are better fitted than one alone to embrace all the sides of a complex question. Peoples of all times, acting under this illusion, have looked to religious or political assemblages for the mitigation of their troubles. In the middle ages, councils—in modern times, states-[illegible]neral, par-

liaments—have been the panaceas demanded by suffering multitudes. The superstition of the jury is the offspring of a similar error, always mistaken and constantly reviving. In reality these bodies were never simple meetings of persons, but rather corporations like certain great religious orders or certain great civil or religious organizations, that have at times responded to the wants of the people. Still it should be observed that, even under their corporative form, collective bodies have shown themselves impotent to create anew. This is the case, however smoothly working may be the mechanism in which they are adjusted and geared. For how is it possible to match in simultaneous complication and elasticity the structure of that cerebral organism which every one of us bears in his head?

As long, therefore, as a well-organized brain excels the best-constituted parliament in rapid and sure performance, in the prompt absorption and elaboration of multiple elements, and in the intimate solidarity of innumerable agents, it will be puerile, however plausible it may seem *a priori*, to count on mass meetings or on deliberative bodies, rather than on one man, to deliver a country from a difficult situation. In fact, every time a nation passes through one of those periods when it has an imperious need of great mental capacity as well as of great heart movements, the necessity imposes itself of a personal government, whether under the form of a republic or of a monarchy, or under color of a parliament.

The preceding considerations may be of use in determining wherein lies the responsibility of leaders for acts committed by the groups which they direct. An assembly or association, a mob or a sect, has no other thought than the one that inspires it; and it matters not that this thought, this more or less intelligent indication of an end to be pursued or of a means to be employed, is propagated from the brain of one to the brains of all—it continues the same. The one who inspired it is therefore responsible for its direct effects. But the emotion associated with this idea, and which is propagated along with it, does not continue the same as it spreads, but is intensified in a sort of mathematical progression; and what may have been a moderate desire or a halting opinion with the instigator—with the first whisperer of a suspicion, for example, ventured against a category of citizens—promptly becomes passion and conviction, hatred and fanaticism in the fermentable mass into which the germ has fallen. The intensity of emotion that moves the throng and carries it to excess, in the good or evil it does, is therefore largely its own work, the effect of the mutual warming up of those souls in contact by their mutual reflection; and it would be as unjust to impute to any one director all the crimes to which this over-excitement may

carry it, as to attribute to him the whole merit of the great deeds of patriotic exaltation and of the great acts of devotion excited by the same fever. We may, therefore, always hold the chiefs of a band or a riot accountable for the astuteness and dexterity it displays in the execution of its maneuvers, robberies, and acts of incendiarism, but not always for the violence and extent of the evils caused by its criminal contagions. The general alone is entitled to credit for the plan of the campaign, but not for the bravery of his soldiers. I do not say that this distinction is adequate to simplify all the problems of responsibility raised by our subject, but it will be well to regard it in trying to solve them.

From the intellectual as well as from other points of view, considerable differences may be established between the various forms of social groups. We do not include those which consist in a simple material bringing together of people. Passers in a thronged street, travelers meeting or thrown together on a packet boat, in a railway carriage, or around a dinner table, silent or without general conversation with one another, are grouped physically, not socially. As much may be said of countrymen congregated at a fair, as long as they do nothing but trade with one another, seeking each his own objects, even though they be alike, without co-operation in any common act. All that can be said of this sort of folk is that they bear in themselves the potentiality of a social group, so far as resemblances of language, nationality, religion, class, or education may dispose them to associate more or less closely, if occasion should require. Should an explosion of dynamite take place in the street, the vessel be in danger of foundering, the train run off from the track, a fire break out in the hotel, or a rumor about some forestaller spread through the market, the associable individuals would at once become associates in the pursuit of an identical purpose under the dominion of an identical emotion.

Thus may arise spontaneously the first stage of the association which we call the mob. By a series of intermediate steps there is raised from this rudimentary, fugacious, and amorphous aggregation, the organized, chief-led, persistent, and regular mob, which may be called the corporation, in the widest sense of the word. The most intense expression of the religious corporation is the monastery; of the lay corporation, the regiment or the workshop. The widest expression of the two is the church or the state. It may indeed be remarked that churches and states, religions and nations, are always tending, in their period of robust growth, to realize the corporative type, monastic or regimental, without, fortunately, ever quite reaching it. Their historical life is passed in oscillating from one type to the other; in giving the impression by turns of a great mob, like the Barbary States, or of

a grand corporation, like the France of Saint Louis. It was the same with what were called corporations under the old system of institutions; they were less corporations in the usual sense than federations of shops, these last very small corporations, each in itself authoritatively ruled by a patron. But when a common danger prompted all the workmen of the same branch of industry to unite for a common end, such as the gaining of a suit, just as all the citizens of a nation would unite in war time, the federative bond was closed up at once, and a governing personality was revealed. In the intervals between these unanimous co-operations, the association confined itself, in the associated shops, to the pursuit of a certain æsthetic or economical ideal, as in the intervals between wars the cultivation of a certain patriotic ideal constitutes the national life of citizens. A modern nation, under the prolonged action of leveling ideas, tends to become again a grand complex mob, directed to a greater or less extent by national or local leaders. But the necessity for hierarchical order in these enlarged societies is so imperious that by a paradox, the more remarkable as they are more democratic, they are often forced to become more and more military.

Between the two extreme poles which I have just marked may be placed certain temporary groups, recruited according to a fixed rule or subjected to a summary regulation, like the jury; or habitual meetings for pleasure, such as a literary *salon* of the eighteenth century, the court of Versailles, or a theater audience, which, although their object and common interest are trivial, accept a rigorous etiquette and a fixed hierarchy of different stations; or scientific and literary conferences—academies—which are rather collections of coexchangeable talents than groups of colaborers. Among the varieties of the species corporation may be named conspiracies and sects, which are sometimes criminal. Parliamentary assemblies are entitled to a place by themselves; they have more of the nature of mobs, complex and contradictory mobs—double mobs, we might say, as we speak of double monsters—in which a tumultuous majority is opposed by a minority or a coalition of minorities, and in which, consequently and fortunately, the evil of unanimity, that great danger of mobs, is partially neutralized.

Mob or corporation, however, all the species of true association have this identical and permanent characteristic, that they are produced, and led to a greater or less extent, by a chief, apparent or hidden; most frequently hidden in the case of mobs, but always apparent and obvious in corporations. From the moment when a mass of men begins to vibrate with an identical tremor, takes life and advances toward its end, it may be assumed that some guiding spirit or leader, or a group of leaders and moving spirits,

among which one is the active ferment, has infected it with his intense and perverted enthusiasm. As every shop has its director, every convent its superior, every brigade its general, every assembly its president, every fraction of an assembly its leader, so every lively saloon has its Coryphæus of conversation, every riot its chief, every court its king, prince, or princelet. If a theater audience can ever properly be regarded as constituting to a certain extent an association, it is when it applauds, because it follows, in clapping, the impulse of an initial applause; and when it is listening, because it yields to the suggestion of the author as expressed by the mouth of the actor who is speaking. Everywhere, then, whether visible or not, there reigns here the distinction between leader and led, so important in fixing responsibility. This is not saying that the wills of all are annihilated in the presence of the will of one; this, too, suggested, the echo of external or anterior voices of which it is only the original condensation—is obliged, in order to impose itself on the others, to make them concessions, and to flatter them in order to lead them. Thus it is with the orator, who has to take care not to neglect oratorical precautions; with the dramatic speaker, who has constantly to bend to the prejudices and changing tastes of his audiences; and with the leader who would manage his party.

Yet the conditions are various according as spontaneous or organized assemblies are in question. In the latter a will to be dominant must arise conformed, in a certain degree, to the tendencies and traditions of the prevailing wills; but once arisen, it executes itself with a fidelity the more perfect the wiser the organization of the body. In mobs an imperative will does not have to conform itself to traditions that do not exist, and may even get itself obeyed, notwithstanding its weak agreement with the tendencies of the majority; but, whether conformed or not, it is always imperfectly executed, and suffers changes in imposing itself. We can affirm that all the forms of human association are distinguished, first, by the way in which one thought or will among a thousand becomes the director of them under conditions of conflict of thoughts and wills from which it comes out victorious; second, by the greater or less facility which is offered in them for the propagation of the directing thought or will.

The objection has been made, with some force,* that the part

* A Russian economist made this objection at the Congress of Criminal Anthropology in Brussels, in August, 1892, citing agrarian risings in his country caused by the famine. More recently an Italian author, from whom we shall quote shortly, has made similar objections. On the other hand, I have learned, while correcting the proofs of this article, that the thesis developed in it has been previously set forth by a distinguished Russian writer, M. Mikhailowsky, in 1882, in a publication entitled Otechestwannia Zapiski.

played by leaders has not, in mobs at least, had the universality and importance which we attribute to it. There are, in fact, mobs without an apparent leader. Famine prevails in a region; on every side the starving masses rise, demanding bread: no chief appears here, but spontaneous unanimity. Let us look a little closer. All these uprisings do not break out together; they follow one another like a powder fuse, beginning with a primary spark. A first riot took place somewhere, in a place suffering more and more effervescent than the others, more exploited by agitators, apparent or secret, who gave the signal for revolt. The outbreak was then imitated in neighboring places, and the new agitators, thanks to their predecessors, had less to do; and from vicinage to vicinage, from mob to mob, their work is propagated with an increasing force that detracts correspondingly from the efficiency of local directors; till at last, particularly after the popular cyclone has spread beyond the bounds where there is any reason for it, or beyond the region of scarcity, no direction can be perceived. Strangely, indeed, to those who do not comprehend the force of imitative enthusiasm, the spontaneity of the uprising then becomes more complete the less motive there is for it.

Taken in one view, all the tumultuous assemblages which proceed thus from an initial riot in intimate connection with one another—a habitual phenomenon in revolutionary crises—may be regarded as a single mob. There are thus complex mobs, as in physics there are complex waves, chains of groups of waves. Placing ourselves at this point of view, we see that there is no mob without leaders; and we perceive, further, that from the first of these compound mobs to the last the function of the secondary leaders goes on diminishing and that of the primary leaders increasing, augmented at each new tumult born of a preceding tumult by a kind of distant contagion. Epidemics of strikes are a proof of it; the first that breaks out, the one therefore where the grievances are most serious and which consequently should be the most spontaneous of all, always leaves defined behind it the personality of the agitators; those that follow, often without the shadow of a reason, have the appearance of explosions without a match. It thus often happens that a mob started by a nucleus of excited persons goes beyond them, absorbs them, and, becoming headless, seems to have no leader. The truth is that it has none in the same way that raised dough has no yeast. The function of these leaders is, finally and essentially, greater and more distinct in proportion as the mob acts with more concentration, consecutiveness, and intelligence, as it comes nearer to being a moral person, an organized association.

It appears, then, that in every case, notwithstanding the im-

portance attached to the character of its members, the association, as a whole, is worth what its chief is worth. His character is the factor of pre-eminent importance; a little less, it is perhaps true, in mobs; but in them, on the other hand, while a bad choice of a chief may not produce as disastrous consequences as in a corporative association, the chances in favor of a good choice are much less. Multitudes and assemblages, even parliamentary bodies, are quick to be infatuated with a fine speaker, with any stranger; but the *collegia* of ancient Rome, the churches of the early Christians, all corporations of every kind, when they come to elect their prior, their bishop, or their syndic, have long been accustomed to examine into his character; or, if they receive him all fitted out, as in an army, it is at the hands of an intelligent and well-informed authority. They are less exposed to "ring rule," for they do not live continually in a single body, but most usually in a dispersed condition that leaves their members, freed from the constraint of contacts, to be influenced by their own reason. Besides, when the excellence of the chief of a body has been recognized, he may die, but his acts will survive him; the founder of a religious order, canonized after his death, continues to act in the hearts of his disciples; and to the influence he exerts is added that of all the abbés and reformers who succeeded him, and whose prestige, like his, grows and is refined by distance in time; while the honest leaders of mobs*—for there are such—cease to act as soon as they have disappeared, and are more easily forgotten than replaced. Mobs obey men, living and present only, men of physical and corporeal prestige, never phantoms of ideal perfection, immortalized memories. As I have just mentioned in passing, corporations in their long existence, sometimes of several centuries, present a series of perpetual leaders, grafted, as it were, upon one another and complementing one another; another difference from mobs, in which there is at most a group of temporary and simultaneous leaders who reflect and aggrandize one another.

There are other differences. The worst leaders are liable to be chosen and endured by multitudes, and the worst suggestions of all that are offered to be adopted. This is because, first, the most contagious notions or ideas are those which are most intense; and, secondly, the most intense ideas are the narrowest and most

* In a conference on Industrial Conciliation and the Function of Leaders, held at Brussels in 1892, a very competent Belgian engineer, M. Weiler, illustrated the useful function which honest leaders—that is, as he expressed it, leaders of the profession, not leaders by profession—might fulfill in differences between employers and their workmen. He also spoke of the little desire which workmen show in these critical moments to see "Messrs. the politicians" come up. Why? Because they know very well that, once come, these gentlemen will subjugate them with or without their consent. It is a fascination they are afraid of, but are nevertheless subject to.

false, striking the senses and not the mind, and the most intense emotions are the most egotistical. This is why it is easier in a mob to propagate a puerile fancy than an abstract truth, a comparison than a reason, faith in a man or suspicion of him than attachment to a principle or renunciation of a prejudice; and why the pleasure of vilifying being more lively than the pleasure of admiring, and the sentiment of preservation stronger than that of duty, hootings are more easily started than bravoes, and spasms of panic are more frequent than impulses of courage.

It has been remarked * that mobs are generally inferior in intelligence and morality to the average of their members. Not only is the social compound in this case, as it always is, dissimilar to the elements of which it is the product or combination rather than the sum, but it is also habitually worthless. This is true, however, only of mobs and aggregations that resemble them. But where the spirit of the organization (*esprit de corps*) rather than the spirit of the mob prevails, it usually happens that the composite, in which the genius of a grand organizer survives, is superior to its existing elements. Accordingly, as a company of actors is a corporation or a mob—that is, as it is more or less trained and organized—its members will play together better or worse than when separately they speak monologues. In a highly disciplined body, like the police, excellent rules for hunting criminals, hearing witnesses, and drawing up processes are transmitted traditionally, and fortify the mind of the individual in its reliance on a higher reason. While we can say with truth, adopting a Latin proverb, that senators are good men and the senate is an unruly beast, I have had a hundred occasions to remark that the *gendarmes*, though generally intelligent, are less so than the *gendarmerie*. A general made the same remark to me while drilling his recruits. Questioned separately concerning military maneuvers, he found them all stupid; but when they were brought together he was surprised to see them perform with a harmony and spirit, with an air of collective intelligence, very superior to what they had shown singly. The regiment, therefore, is often braver, more generous, and more moral than the soldier. Doubtless, corporations, whether regiments, religious orders, or sects, go further than mobs both in mischief and in well-doing; from the best disposed mobs to the most criminal is a less distance than from the noblest exploits of our armies to the worst excesses of Jacobinism, or from the Sisters of St. Vincent de Paul to the Camorrists and the anarchists; and M. Taine, who has depicted with much vigor criminal mobs and criminal sects, has shown that the latter were more mis-

* See, on this subject, a very interesting essay by M. Sighele, on La Folla delinquente, which has been reviewed by M. Cherbuliez in the Revue des Deux Mondes.

chievous than the former. But while mobs more frequently do ill than good, corporations more frequently do good than ill.

When, by chance, a multitude in action appears to be better, more heroic, and more magnanimous than the average of those who compose it, the fact is either due to extraordinary circumstances, or the magnanimity is only apparent and fictitious, and is the deep-seated result of a hidden terror. The heroism of fear is frequent in mobs. Sometimes the beneficent conduct of a mob is simply a survival of the custom of an ancient corporation. Is not this the case in the spontaneous self-devotion which is sometimes exhibited in the crowds which in cities run to put out a great fire? I say *sometimes* of them, not referring to the body of the firemen, in whom these admirable traits are habitual and exhibited daily. The multitude around these, following their example, perhaps stimulated by emulation, show also a rare devotion, and confront a danger to save a life. But when we observe that these collections of the multitude are a traditional affair, that they have their rules and customs, that they portion out duties, that the full buckets go round on the right and the empty ones on the left, that their actions are combined with a customary act rather than being spontaneous, we are brought to perceive that these manifestations of sympathy and of fraternal assistance have come down from the peculiar corporative life of the communities of the middle ages.

Instances in any number might be cited to illustrate how an excited multitude, even when the majority of it are persons of intelligence, has always something in it partaking both of the puerile and the bestial: of the puerile in the mobility of its humor, in its quick passage from rage to outbursts of laughter; of the bestial in its brutality. It is cowardly, too, even when composed of individuals of average courage. It is hard to conceive to what extent mobs, and unorganized, undisciplined collections of men in general, are more mobile, more forgetful, more credulous, and more cruel than the greater part of their elements; but the proofs of the fact are abundant. In the collective mind images succeed one another incoherently, as they do in the brain of a sleeping or a hypnotized man; while most of the individual minds which compose it, and which concur in forming that great folly called opinion, are capable of consecutiveness and order in the arrangement of their ideas. M. Delbœuf tells of a poor German, just arrived at Liége, who followed the crowd to the scene of a dynamite explosion. Some one, seeing him run a little faster than the others, pointed him out as the guilty person, and the whole mob was ready to cut him to pieces. Yet that mob was composed of the best society of the place, attending a concert; and gentlemen could be heard calling for a revolver

with which to kill recklessly an unhappy man of whose nationality, name, and crime they knew nothing.

When the cholera was raging in Paris in 1832, the report spread through the city rapidly that the disease was the work of poisoners, who, the people were brought to believe, were tampering with food, wells, and wines. Immense multitudes assembled in the public places, and every man who was seen carrying a bottle or a vial or a small package was in imminent danger of his life; the mere possession of a flask was sufficient evidence to convict, in the eyes of the delirious multitude; and many fell victims to its rage. Two persons, flying before thousands of madmen accusing them of having given a poisoned tart to children, took refuge in a guardhouse; the post was surrounded in an instant, and nothing could have prevented the murder of the accused men if two officers had not conceived the happy thought of eating one of the tarts in full view of the mob. The mob burst into laughter, and the men were saved. These follies are of all kinds, and the mobs are of every race and every climate—Roman mobs, charging Christians with the burning of Rome or the destruction of a legion, and throwing them to wild beasts; mobs of the middle ages, entertaining the most absurd suspicions against the Albigenses, the Jews, or any heretic, the spread of which was independent of proof; German mobs of Muzer in the Reformation; French mobs of Jourdan in the Reign of Terror—the spectacle is always the same. The inconsistency of mobs is illustrated by what Dr. Zambuco Pasha relates of certain Eastern villages where leprosy exists; where the populace are ready to chase any one suspected of having leprosy, and even to execute lynch law upon him; yet the same populace go to chapels attended by leprous persons, kiss the images they have kissed, and take the communion from the same chalices with them.

Mobile, inconsistent, and without real traditions as mobs are, they are, nevertheless, subject to routine; and in this they differ from corporations, which in their whole period of ascendency are traditionalist and progressive, and progressive because they are traditionalist. The power of routine over men casually brought together was curiously illustrated to me a few years ago at the rooms of a cure by inhalation at Mont Doré, where the three or four hundred men assembled to take the vapors issuing from a boiler in the middle of the apartment, having nothing to do or say, proceeded to march in procession around the room, and always walked in the same direction—that of the hands of a watch; and all efforts to start them in the opposite direction failed. An instance of the power of suggestion to start the crowd was furnished in a dissecting room, where the work could be carried on in the midst of conversation or singing. Some one would break

the silence by singing a measure or two of an air, and then stop. Instantly the strain would be taken up and carried on by another student working in another part of the room. The person who continued the song, when questioned on the subject, did not seem aware that he had followed any definite impulse. Is there not in this often unconscious suggestion something that casts a light on those ideas that come up, one knows not why or how, in mobs that come, no one knows whence, and spread with dizzy rapidity?

An audience in a theater suggests similar remarks. While it is the most capricious of publics, it is also the most sheeplike, and it is as hard to foresee its caprices as to reform its habits. Its ways of expressing approbation or blame are usually the same in the same country; then it must always be shown what it is accustomed to see on the stage, no matter how artificial it may be; and it is not safe to show it what it is not accustomed to see there. Still, it must be remembered that the theater audience is a seated mob—that is, only half a mob. The real mob—that in which electrification by contact reaches its highest point of rapidity and energy—is composed of people standing and, better yet, in motion. Yet the most effective agents of mutual suggestion, especially the sight, still exist among seated spectators; and, no doubt, if they did not see one another, if they were witnessing the play as prisoners in cells hear mass in little grated boxes whence it would be impossible to look around, each of them, influenced by the action of the piece and the actors, free from all mixture with the action of the public, would be more fully controlled by his own taste, and the applause or hissing would be much less unanimous. It rarely happens at a theater, a banquet, or any popular manifestation, that one—even if he at heart disapproves the applause, the toasts, or the hurrahs—dares to withhold his applause, or not to raise his glass, or to keep an obstinate silence in the midst of enthusiastic cries. At Lourdes, in the processional and praying throng of believers, there are skeptics who, on the morrow, thinking over all they have done to-day—the crossing of their arms, the expressions of faith uttered by some and repeated by all the others, and the prostrations—will jest about them. They will, nevertheless, not laugh or protest to-day, but will themselves kiss the ground, or pretend to, and if they do not actually hold their arms crossed, will make the gesture of it. They are not afraid, for there is no force in these pious throngs: but they do not wish to be scandalized. And what, at the bottom, is this fear of scandal except the extraordinary importance attributed by the most dissenting and most independent of men to the collective blame of a public composed of individuals, for the personal judgment of each one of whom he would not care a whit? This, however, is not always sufficient to explain the

habitual and remarkable condescension of the unbeliever to the fervent multitudes in which he is immersed. We must also, I believe, assume that at the moment when a wave of mystic enthusiasm passes over them he takes his little part of it and finds his heart traversed by a fugitive faith. This being admitted and explained for pious crowds, we have a right to explain in the same way what passes in criminal mobs, where a current of momentary ferocity sometimes crosses and denaturalizes a normal heart.

It is a trite piece of exaggeration to glorify civil courage at the expense of military courage, which passes for something less rare; but the truth there is in this trite idea is explained by what has just been said. Civil courage consists in resisting a popular enthusiasm, in going against a current, in uttering before an assembly or a council a dissenting, isolated opinion, opposed to that of the majority; while military courage consists, generally, in distinguishing one's self in battle, in yielding most completely to the environing impulse, and in going further than the others in the direction that one is urged by them. When, in an exceptional case, military courage requires one to resist an impulse, when a colonel has to oppose a panic, or to restrain the inconsiderate eagerness of troops, bravery of that kind is still more rare, and, let us acknowledge, is more admirable than an opposition speech in the legislative chamber.—*Translated for The Popular Science Monthly from the Revue des Deux Mondes.*

THE DISTRIBUTION OF GOVERNMENT PUBLICATIONS.

By Prof. EDWARD S. MORSE.

IF there is any one portion of government machinery that would seem to demand a readjustment it is that portion which has to do with the distribution of public documents. I am not aware that there is any central bureau for the judicious distribution of the various publications of Government as there is, for example, for the issuing of patents or the payment of pensions. There is no government in the world more generous in the distribution of its multifarious publications than ours. The niggardly way in which Great Britain doles out her public documents has repeatedly excited the most adverse criticism from her own people. Knowing, as every one does, the slightly increased expense of printing extra copies after the first expense of composition, engraving, etc., has been provided for, it is most exasperating to see a rich country like Great Britain publishing the

results of some important expedition, like that of the Challenger, for example, and not printing enough copies to meet even the hungry demand of her own special students. We have never erred in this respect, and in the scathing comments which this particular English frugality has received from her own men, our country has invariably been held up in striking contrast as an example to imitate. With the liberality of the General Government in this respect it is a pity that the distribution of printed matter should not be better systematized. There are many documents that doubtless represent official reports which are circulated not so much for instruction as to inform the country just what has been done by certain bureaus, and these probably reach the proper parties, in being sent to those prominent in governmental and political matters. With these we are not concerned. There are many other publications, however, that are issued solely for the purposes of information and instruction in lines of thought in which there are hundreds, perhaps thousands, of students in the United States. It is obvious that if these kinds of documents are issued to advance learning, then such copies, as are freely distributed through the mails should go to those who most need them. The present distribution of many of them is so imperfect that it would be paralleled by the Pension Bureau issuing a certain number of money checks to congressmen and senators to scatter where they pleased, or to realize on them if they were so inclined. Let me make this clearer. So far as I have been able to ascertain, the regular edition of a public document is nineteen hundred. From this edition fifty foreign governments, and the larger libraries and institutions in this country are each supposed to receive a copy. Each senator and congressman is entitled to two copies, and probably more for the asking. It is a common belief that many of these men dump their public documents into the waste-paper barrel, for the janitor to realize upon as old paper, which at one time had some value. As a matter of fact, many of them are sold to the junk shops, where they find their way into the secondhand book stalls; and students who want them are grateful for even this opportunity of securing them by purchase. It would certainly seem that a report which is of special interest to a greater or less number of students and writers should in some way get to them, and that their names should be on some permanent list at headquarters, so that when any report in their special line of thought is published they should be among the first to receive it. Not only is it evident that the Government publications often fall into the wrong hands, but, worse still, hundreds of thousands of volumes are rotting in the cellars of the Capitol and vitiating the air by their decomposition. A committee recently appointed by the

House, to look into the question of fresh air has just discovered that certain rooms in the basement of the Capitol are filled with Government publications. In one series of vaults were one million two hundred and fifty thousand volumes, and many of these have been stored for thirty years. "They present a vast bulk of decomposing vegetable matter, which is constaintly tainting the atmosphere with impurities."

One reason of the apathy of the people in regard to the waste of public documents is that being free they are supposed to be valueless, and to many who receive them they have no value. In the rural regions they are used as scrap-books by the children, and there is hardly an attic in the land that does not contain a few of this kind of books, mixed with the usual light truck which ascends to the garret.

There is certainly nothing to complain of in the scientific departments of the Government. The valuable contributions published by the various scientific bureaus, have been distributed in such a way that special students get, without much trouble, the works needed in their studies. So far as I know, but few if any of these drift into the wrong channels. There are special reports of an ethnological character now and then appearing in other departments, notably in the United States consular reports, and subjects pertaining to other sciences issued from other bureaus, and these would be priceless to certain special workers, yet such reports are usually exhausted when application is made for them. I have often secured Government publications of the greatest value by overhauling a lot of stuff which some lawyer was about to throw away. Reports that I had never heard the existence of have come to me in this manner. Lately I had given to me from an editor's room several shelffuls of pamphlets, books, etc., which were on their way to destruction. Among these were many public documents on various subjects, and these were distributed to those whom I knew would make good use of them. Among the letters of acknowledgment was one from a gentleman who has made a special study of the seal-fisheries dispute, and has written a number of reviews on the subject. This letter came in return for a government report containing a lengthy legal opinion about the seal fisheries, and is as follows: "Ever so much obliged to you for the document. I devoured it right off, and then took it up to the Harvard Law Library, where they were no less pleased to get it. They had never seen it nor heard of it, and seemed to be amused at the idea of their obtaining it through two such outside barbarians in law matters as you and I." This is by no means an exceptional case.

A public library of nearly forty thousand volumes in a neighboring city finds it impossible to get anywhere near a complete

set of current Government reports; and yet it is plain enough that all public libraries in the United States, no matter how small, should be entitled to receive such publications of the Government as bear on science, education, etc., provided they ask for them and indicate a willingness to provide shelf room.

It is also said that documents are distributed as political favors, and thus, during a change of administration, these currents flow in other directions. The power to scatter such documents should be entirely out of the hands of politicians, and a central bureau should be organized whose duty it should be to keep lists of all persons making researches in the various departments of science, law, education, etc. Senators and representatives might be empowered to furnish these names, accompanied by evidence, however, that such persons had a right to them by virtue of their studies or occupations.

I know as a fact that many who receive these reports and documents are actually burdened with them, and often throw them into the waste-paper basket unopened, and there are hundred of others who would like them, and would make good use of them, and yet never get them. All this might be corrected by some systematic way of distribution from a common center.

If I were permitted to offer suggestions upon a matter with which I can claim but little knowledge, I would ask first that for convenience of reference there should be published each year a volume containing a list of all Government publications, with at least a table of contents of each report, and if possible a brief synopsis of the more important papers. Students would then have an opportunity of finding out the material they were in quest of. In the same volume should also be given a classified list of the recipients of Government reports, and this list should be kept standing for additions and subtractions. This annual report could be printed in the most condensed form, the matter solid, the covers paper, etc. Such a report should find its way into every school, college, and public library in the United States and to every one applying for it. It should be as common as an almanac. A list of publications of this nature might possibly show what appears to many the disjointed character of some of the series and lead to simplification. The Government goes on forever, yet with every new chief of department or change of administration comes a new series of parts or volumes, to the misery and despair of bibliographers. The hungry ambition of species describers might be curbed by checking the issue of *separata* of one or two pages.

If it were possible to establish a separate bureau of distribution, it would lead to economy of administration, to the economical and efficacious distribution of reports, the avoidance of duplication, and consequently the placing of material where it would

do the most good, or at least where it would not be used to kindle the kitchen fire.

The above suggestions refer solely to those reports which tend to the advancement of human learning, and, printed and distributed freely as they are by the nation, should reach in every case those who stand most in need of them.

THE STORY OF A GREAT WORK.

By J. JONES BELL.

ON the 19th of September, 1891, Sir Henry Tyler, President of the Grand Trunk Railway Company, presided at the inauguration of one of the greatest engineering achievements of the present day, bold in conception, new in design, and novel in many of the methods adopted in its construction. Without the St. Clair Tunnel the immense stream of traffic from the East, which during last summer flowed to the World's Columbian Exposition at Chicago, could not have been successfully handled.

Previous to the construction of the tunnel, connection between the Grand Trunk Railway and the Western roads with which it exchanges traffic was maintained by a ferry, the loaded cars being carried across on the deck of a powerful steamer, specially built for the purpose. Adopted for want of a better, this service was never satisfactory. Though the swift current, where Lake Huron pours its entire volume through a narrow outlet, prevents the river freezing in winter, ice blocks occasionally occurred, and a single day's interruption to traffic involved serious inconvenience and loss. A bridge had often been suggested, but it was always successfully opposed by the vessel interest. A larger number of vessels, with a greater tonnage, pass up and down the St. Clair River during the season of navigation than through the Suez Canal in a year. A high-level bridge is impossible, and a draw would be attended with great interruption to traffic, and danger to vessels on account of the current. The only alternative seemed to be a tunnel. Its completion not only affords a better crossing, but establishes the possibility of such a work being successfully and economically built and worked where favorable conditions exist. The story of its construction is an interesting one.

The tunnel is really a large iron tube, twenty feet in diameter and six thousand and twenty-six feet long, buried under the river, but considerable ingenuity was required to place it there. In 1884 Mr. Joseph Hobson, the chief engineer of the work, and Mr. Hillman, his assistant, made a survey of the river, one mile be-

low the towns of Sarnia and Port Huron. Though not so narrow as where the cars were ferried, the nature of the bed of the river seemed to be more favorable at that point. Borings were made to the rock, eighty-six feet below the level of the river. The greatest depth of water was 40·47 feet. The bed of the stream was found to consist of the following layers: two feet of common yellow sand like that of the seashore, twelve feet of a mixture of quicksand and blue clay, twenty-one feet of blue clay of an adhesive and putty-like character and increasing in density, and then the rock. In 1886 a company was organized, and in January, 1889, the work was commenced. After various tests and experiments, necessary from the difficulty of boring through quicksand and clay under water, and near rock full of fissures from which natural gas escapes, two great excavating shields were started, one on each side of the river. Two cuttings were made, one on the Canada side fifty-eight feet deep, and one on the United States side fifty-three feet deep, into which the shields were lowered ready to begin their work. The shield on the United States side commenced on the 11th of July, that on the Canada side on the 21st of September. They met on the 30th of August, 1890, after traveling six thousand feet. The work had proceeded day and night, by the aid of the electric light, three gangs of men having been employed, in shifts of eight hours. Each shield averaged ten feet per day, and the most accomplished in any one day was twenty-seven feet and ten inches.

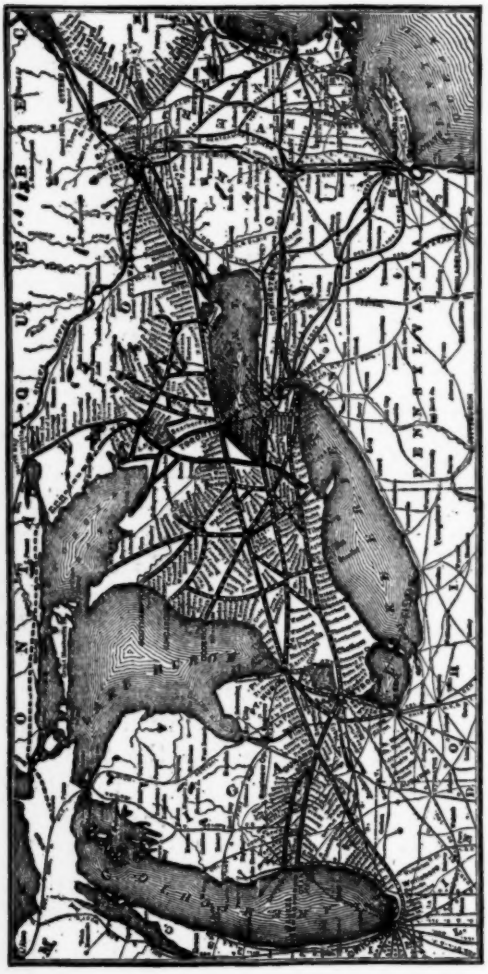


FIG. 1.

The tunnel could not have been built without this shield. The credit of its invention appears to be due to Mr. Alfred E. Beach, of New York, who designed it in 1868 for use in the construction of the tunnel under Broadway. It was subsequently used in Buffalo, Chicago, at the Hudson River Tunnel, and other places. The use of the shield in tunneling was first introduced by Sir Mark I. Brunel in 1825, and it was afterward employed by Mr. Greathead, in the Thames Tunnel and other works; but the St. Clair shield differs in some important respects from any before employed. It is a cylinder of iron, twenty-one feet and six inches in diameter and sixteen feet long, built of steel one inch thick, and with a sharp cutting edge in front. It is divided into twelve compartments by two horizontal and three vertical stays. It weighs fifty tons, and was built on the spot, the material having been prepared in the workshops at Hamilton. Against the rear end of the shield were ranged twenty-four hydraulic rams, eight inches in diameter and having a stroke of twenty-four inches. These forced the cutting edge forward into the clay, which was then excavated within the shield. By means of a Worthington pump, a pressure of five thousand pounds per square inch, or three thousand tons in all, could be exerted. The greatest pressure used was seventeen hundred pounds per square inch, or a thousand and sixty tons in all. The pressure could be exerted on any or all of the rams so as to preserve the true direction of the shield. The keeping of this direction was one of the interesting engineering feats of the work. It was done by means of a specially made London transit, set on masonry, a series of disks and cross-wires indicating the slightest deviation.

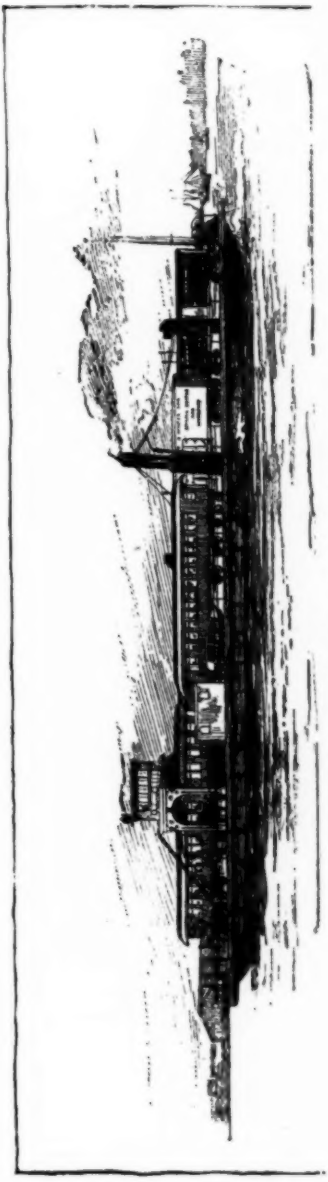


FIG. 2.—THE OLD RAILROAD FERRY.

Observations were made every day and the results marked on a diagram. The deviation was rarely found to exceed a quarter of an inch, and any error was corrected by adjustment of the hydraulic jacks. When the shields came together they were found to be exactly in line.

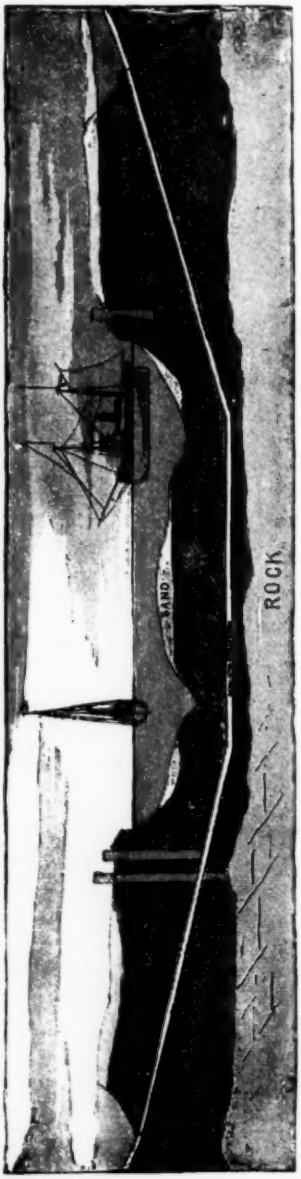


FIG. 3.—LINE OF EXCAVATION OF THE ST. CLAIR TUNNEL.

At one time it was feared the work would have to be abandoned. When the tunnel from the Canadian end reached the bed of the river, quicksand and water caused much trouble, but by the use of compressed air the difficulty was surmounted. At the line of the river on each side a bulkhead of brick and cement was built across the tunnel, with two air chambers, provided with airtight doors. The greatest atmospheric pressure necessary to prevent an inroad of sand and water was thirty-seven pounds per square inch, and under this pressure, after a short experience, the workmen found no difficulty in pursuing their task, in half-hour shifts. The use of compressed air had to be resorted to at two points.

The completed tunnel, as already stated, is an iron tube. This tube is built up of rings, eighteen inches in width, one of which was put together within the shield each time it was moved forward. Each ring consists of thirteen sections and a keypiece, flanged to enable them to be bolted together. The body of the section is two inches thick, and the flanges are six inches wide. Each section weighs about one thousand pounds. The pieces were lifted and placed in position by a revolving crane, a complete ring being put up in about one hour. To ease the pressure and make the joints watertight, the edges were planed and strips of oak and tar canvas inserted. The sections were also heated and dipped in pitch. The tube being only twenty-one feet in diameter, while the shield was twenty-one feet

and a half, the space under the tube when the shield moved forward was filled with cement. The clay was allowed to settle down on the upper part. When the shields met, the tube was built up within them to the junction and the shells of the shields allowed to remain. The inside of the tube is finished with a preparation to keep it from rusting.

On Sunday, August 24, 1890, the two excavations had approached so nearly that an opening was made with an earth auger, and the workmen talked and passed articles to each other. The earth was soon removed, and Mr. Hobson, the chief engineer, and others connected with the tunnel company, stepped through. Six days later the shields came together and the success of the great undertaking was assured. In its construction about seven hundred men were employed, of more than average intelligence, who took great interest in the work.

The actual length of the tunnel, from portal to portal, is six thousand and twenty-six feet. Of this, two thousand three hundred and ten feet is under the river, one thousand nine hundred and eighty-two feet under dry ground on the Canada side, and seventeen hundred and thirty-four feet under dry ground on the United States side. The open excavation to reach the ground level on the Canadian side is three thousand and sixty-one feet, and on the United States side two thousand four hundred and sixty-six feet. The grade is one in fifty, except under the river, where it is practically level, only sufficient incline—one tenth per cent—being given toward the Canadian side to provide for drainage. The depth of the lowest part under the mean level of the river is 77·83 feet. The minimum depth between the top of the tube and the bottom of the river is fifteen feet, the average being twenty-five feet. It was necessary to place it as far down as possible in the clay, consistent with the grade, so as to overcome the tendency of a tube filled with air to rise to the surface in water or mud. The bottom is about nine feet above the rock which underlies the clay. On the Canada side the bottom is sixty feet below the surface of the ground at the portal, on the United States side it is eight feet less. The bottom of the tunnel at its lowest point is one hundred feet below the railway track on the level, which indicates the total ascent and descent which trains have to make in passing through. Ventilation is secured by the motion of the trains, which is found to be ample for the purpose.

The trains are drawn through the tunnel by powerful locomotives belonging to the tunnel company, specially built for the purpose. They take eighteen loaded cars at a trip.

The track in the tube is supported on solid brickwork, as shown in the accompanying cross-section. It was at first proposed to build the tunnel wide enough for two tracks, but it was found

that two single-track tunnels would be cheaper, and one of them would sooner be available for traffic. Experience has proved that a second tunnel will not be required for a long time. The largest number of freight cars passed through in twenty-four hours

FIG. 4.—SECTION OF THE TUNNEL AND RIVER-BED.

during the two years the tunnel has been in use was one thousand and fifteen, while twenty-five hundred could be handled if occasion required. The average number is seven hundred in

winter and five hundred in summer. This is in addition to passenger trains.

The estimated cost of this great work was between two and a half and three million dollars, but its actual cost was considerably less, a rather remarkable fact in connection with such works. Owing to the great risk any contractor would have to assume, and the large sum required to cover that risk, the work

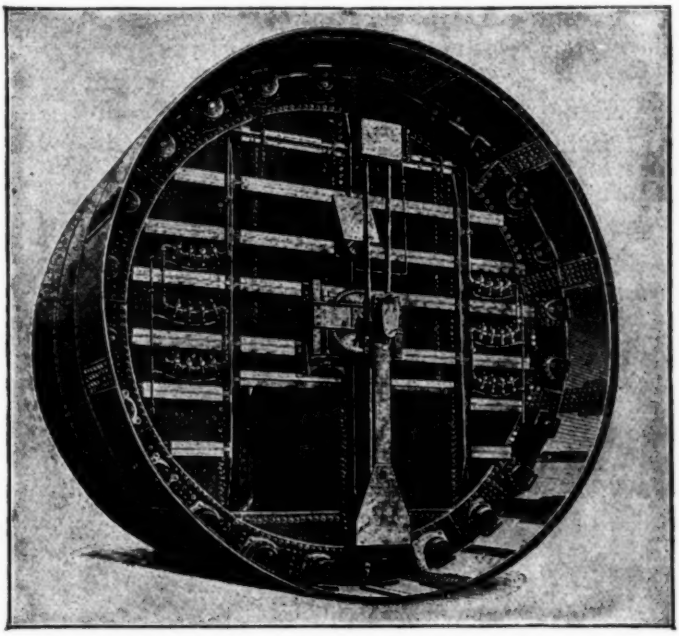


FIG. 5.—SHIELD USED IN THE TUNNEL EXCAVATION.

was performed by the company, only the material being contracted for.

The opening ceremonies were attended with much *éclat*, as became the completion of such a work, uniting not simply two towns but two nations, and rendering possible a greatly increased international trade when the tariff barriers which now stand in the way are removed. It was proposed to spread the banquet in the tunnel, beneath the waters of the St. Clair, with the Governor-General of Canada seated on one side of the international boundary line and the President of the United States on the other, but this part of the programme had to be abandoned. The banquet, to which three hundred guests sat down, after they had passed through and formally opened the tunnel, brought together a greater number of notable men in the world of science, literature, and politics than had ever before gathered in a similar manner in Canada.

Speaking of tariff barriers recalls the fact that the sections for the ends of the tube were made in different places—those for the Canada end in Hamilton, and for the United States end in Detroit—so as to avoid the payment of duty.

To Joseph Hobson, a native Canadian, is due, more than to any other man, the successful completion of this great work. He was its architect, designer, and builder, and though his proposals did not, at the outset, meet with much encouragement from engineers, the result fully justifies the confidence reposed in him by Sir Henry Tyler, President of the Grand Trunk; Sir Joseph Hickson, its former general manager; and Mr. Seargeant, Sir Joseph's successor, all of whom ably seconded Mr. Hobson. It is a fact worthy of note that Mr. Hobson received all his professional

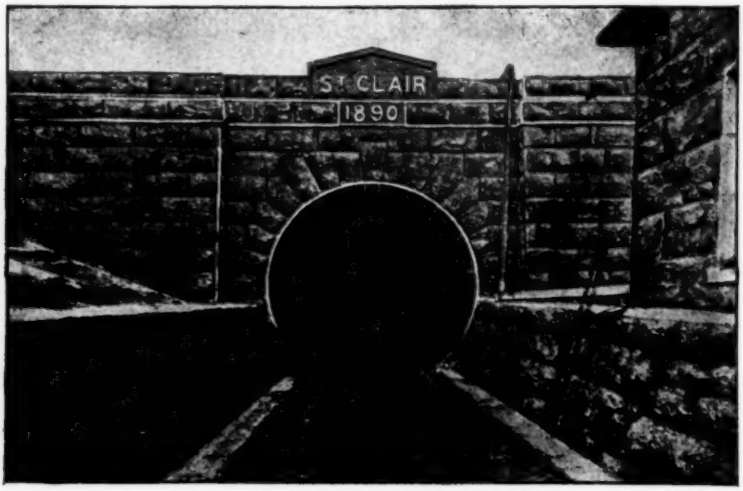


FIG. 6.—ENTRANCE TO TUNNEL.

training on the continent of America, never having been farther east than the city of Quebec. He is a member of the Institutes of Civil Engineers of England, America, and Canada, and has established his right to rank among the first engineers of the world.

The successful completion of the St. Clair Tunnel will doubtless be followed by the construction of many similar works. In 1872, when the Great Western Railway of Canada—now a part of the Grand Trunk—was an independent line, tests were made for a tunnel under the Detroit River, and a drainage tunnel excavated for some distance. Quicksand was met, and, the shield and iron tube not having been adopted for tunnel work, it had to be abandoned. The project has been revived, and if, on fuller investigation, the conditions are found favorable and the work carried out,

there will be a tunnel over twelve thousand feet long and twenty-seven feet in diameter, to accommodate two tracks. The Michigan Southern has also been making tests at its crossing, a short

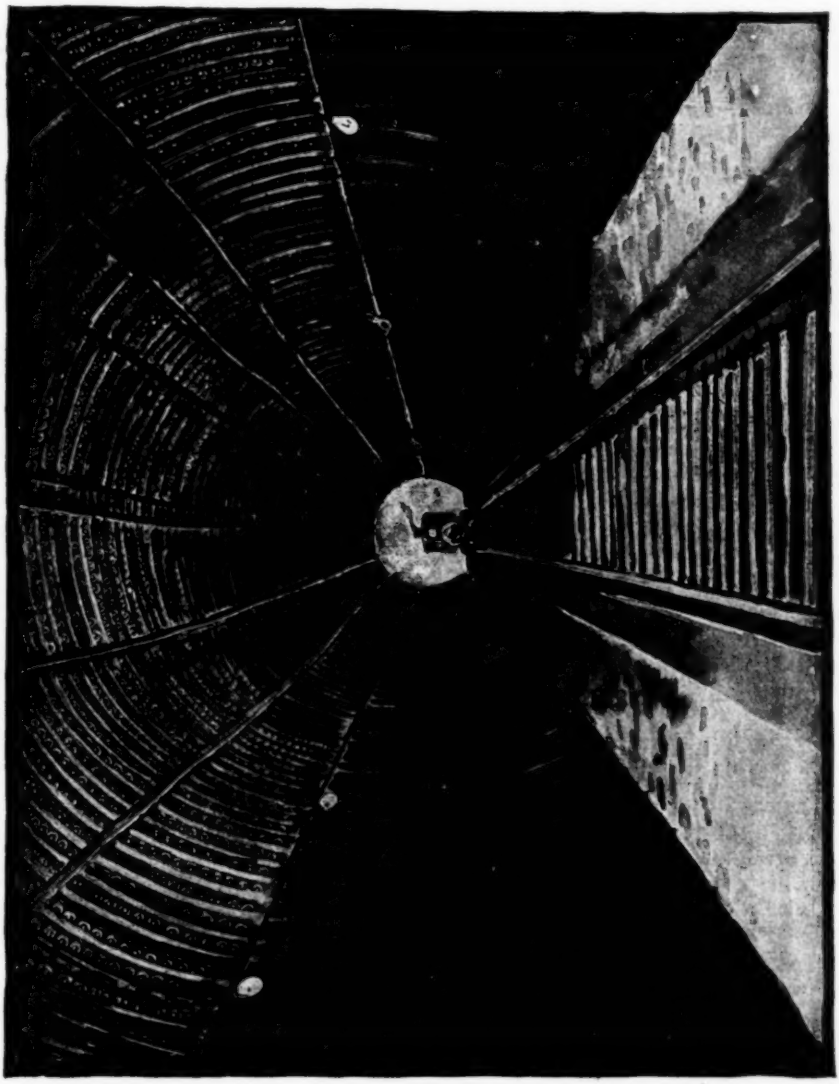


FIG. 7.—INTERIOR OF TUNNEL.

distance below Sarnia, but the strata are not favorable for tunnel construction.

One of the remarkable features in connection with the St. Clair Tunnel is the rapidity with which it was constructed. The average advance was 455·4 feet per month. Contrast this with the Thames Tunnel, three thousand six hundred feet long, which was commenced in 1825 and not completed until 1843, though work

was, it is true, suspended for a time. A curious incident, bearing on the rapidity of construction, is related. A cooper, who could not obtain work at his own trade, applied for employment, and was put with the excavators in the shield. He was not accustomed to the use of the spade or shovel, the drawknife being his tool. It was hard work digging the tenacious clay with a spade, the only effective tool in its removal being a long, narrow spade, such as tile-ditchers use in England. The next day the cooper appeared with a drawknife of semicircular form, about six inches across, and, despite the jokes of his fellow-workmen, set to work with it. It was soon found that he could shave away the clay much more rapidly than it could be dug out. All the workmen were soon provided with drawknives, and it is probable that tool has come to stay as a means of tunneling in sticky clay.

The accompanying illustrations will give an idea of the character, progress, and appearance of the work after completion.

A PROPOSITION FOR AN ARTIFICIAL ISTHMUS.

By ERNEST A. LE SUEUR.

A STUPENDOUS scheme has recently been seriously suggested for the utilization in British waters of the energy of ocean currents for the purpose of distribution of power and light by means of electricity to centers of population at distances up to hundreds of miles from the source. This is nothing less than the proposition to dam the Irish Channel at the Mull of Cantire, where the distance between the Scotch and Irish shores is only fifteen miles, and where the energy of the current from the north is, so far as human requirements go, infinite—that is, would have to be expressed in scores of millions of horse power.

That this proposition is being regarded with some degree of seriousness may be gathered from the fact that a series of hydrographic surveys of the bottom of the channel has been made and charts prepared of the coasts and of the highlands on both sides from which materials might be conveniently got for building the dam. The report of an engineer detailed for the purpose is to the effect that there are no engineering difficulties in the way; by which is meant that, given the means to proceed, it is a possible thing to do, and is, compared, for instance, with the erection of the Brooklyn Bridge, a piece of work requiring merely enough brute force.

The idea is not primarily to afford a land junction for purposes of easier communication—although, of course, if the dam were constructed, a railway would be laid across—but, as mentioned, to give

an opportunity of utilizing the tidal power. There is a continuous flow from the north (due in the first place to the Gulf Stream), estimated at between one and two hundred cubic miles per day. If a dam were thrown across, the effect would be to turn the Irish Sea into a bay and to bank the waters of the North Sea a number of feet higher on the north side of the dam than the level of the now Irish Channel on the south. From this difference of levels an unlimited quantity of power could be drawn. One can get a faint conception of the amount that would be on tap by comparing the case with that of the utilization of the energy of the Falls of Niagara. There is at present in course of construction at the falls a vast scheme of power development which will supply one hundred thousand horse power day and night all the year round. The amount of water which this will take will be insignificant compared with the total quantity going over the falls, which is roughly estimated at three hundred and fifty thousand tons *per minute*, and one hundred thousand horse power will be developed by about thirteen thousand tons per minute. The total power on the falls is thus some twenty-seven times the one hundred thousand horse power. This total quantity of water amounts to about one cubic mile every nine days, and the volume of water running through the Irish Channel is about one hundred and fifty cubic miles daily. Of course, the number of feet of fall is many times greater at Niagara than it would be at the proposed dam, but even so the total horse power available at the dam would be more than fifty times that of the whole of the Niagara Falls.

The site of the proposed undertaking is between the headlands of Antrim and Cantire. On both sides the ground is described as high, and on the Irish side there rise several peaks of considerable height, viz., from nine to twelve hundred feet. These are sufficiently near the shore to be used to dig materials from to be gravitated down to the dam, and the fact is of great importance in connection with reducing the expense of the work by doing away with the necessity for power for the traction of these materials.

The channel is, as has been said, some fifteen miles in width and of varying depth. The average depth is about three hundred feet, and the maximum is given by Mr. Lodian, in the Electrical Engineer of January 24th last, as four hundred and seventy-four feet; in many places it is as little as two hundred. The bottom is described as of "shells, stones, and rock," which would probably hardly settle at all under the weight of the dam. The current is six or eight miles an hour, varying somewhat at different points in the cross-section of the channel. The total quantity of material necessary to form the dam or isthmus would be in the neighborhood of five hundred million cubic yards. One can imagine that

this amount of material removed from the crowns of a few high hills in the vicinity would alter the landscape considerably, and that this alteration, together with the turning of the Irish Sea into a landlocked bay, might confuse a person acquainted with the locality only as it had been before the commencement of the work. The territory to be acquired for the land work would not be expensive, as the country on both sides is almost desert.

It is proposed to construct two generating plants near the two shores respectively, each to be used to supply the country to which it is nearest. In order not to interfere with navigation, it is suggested to enlarge the canal of Crinan and to make a cut through the isthmus of Tarbert. To the writer it does not seem that these means would be better than simply to cut through the dam and provide suitable locking facilities.

One of the remarkable results which, it has been pointed out, would flow from the construction of such an artificial isthmus is the lowering of the level of the Irish Sea along the east coast of Ireland, and thus rendering the marsh lands in that section capable of receiving a high degree of cultivation.

Besides the great interest that any such plan must have in itself, from the fact of the important change in the geography of the British Isles which it would bring about, the results that would flow from a utilization of a part of the tidal power for distribution throughout the kingdom are most impressive. Our means for the distribution of power electrically have developed, within the past year or two even, to an extraordinary degree. Two years ago it was possible to transmit electricity for lighting purposes a great number of miles from the point of generation, but it was not commercially possible so to distribute electricity for power purposes. The reason for this is that in order to have electricity in a safe form for use in houses, mills, or car lines it must be supplied at low voltage (or electrical pressure); on the other hand, if we are not to use an utterly prohibitive weight of copper conducting wire we must transmit at high voltage. What is done, therefore, is to transmit at, say, ten thousand volts and transform at the consuming end down to anywhere from five hundred to one hundred volts; the trouble is that there is no practical way of transforming direct currents, and until recently the alternating could not be used to work commercial motors. Now, however, due largely to the work of Mr. Nikola Tesla, we have motors that operate at very good efficiency on alternating circuits. The methods of insulation and of polyphase transmission have, moreover, been improved greatly within a year or two, and these have brought up the capabilities of the wire both for carrying more current and working at higher voltage than was before the case. In the present state of the art it would be safe for an electrical engineer

to contract to transmit any amount of power one hundred and fifty miles with a total loss on the line, due to fall of voltage, or "drop," and leakage, of not more than twenty-five per cent, and this without being too extravagant of copper. The voltage on such a line would be, however, much more than that referred to above—probably twenty-five thousand volts.

The distance from the Scotch side of the proposed line to London by air line is three hundred and sixty-five miles, and it is only reasonable to expect that the first decade of the twentieth century will see things so perfected as to admit of transmission over this distance of any desired amount of power. As it is, the great power-consuming counties of York and Lancashire, particularly the former, would to-day be accessible from the proposed power generators.

If we glance at the ultimate results of all this, we shall see them to be enormously far reaching. The limit to Britain's commercial greatness may be set, as things are now, at the giving out of her coal mines. These are not by any means inexhaustible, and the drain upon them is something awful. The amount used in generating power alone is annually in the scores of millions of tons, and this is over and above what is used for house-heating, cooking, etc.

Suppose now that there comes from the north an inexhaustible supply of electric energy—inexhaustible, that is, as regards the driving power it draws on, and limited in practice only by whether one is willing to pay the moderate price that its generation, transmission, transformation, etc., cost—we should have here a solution of the whole question of the future of the coal fields. The electrical power would be sufficiently cheap for general use, and in the great textile manufacturing districts the hum of the hundreds of thousands of cotton and woolen spindles would be supplemented by the lower note of the driving motors. Electric heating for culinary purposes is pre-eminently satisfactory, not only for its cheapness, since one can use the heat just where it is needed and avoid the waste of ninety-five per cent of the heat employed due to hot air going up the chimney of a cooking range and to radiation to an already overhot kitchen, but also on account of its entire cleanliness and reliability. If the price of coal should go up at all seriously, due to prolonged strikes, or to other causes, it would pay to use electricity for even house and store heating. In the vast iron-smelting industry it could be applied to at least greatly reduce the amount of fuel at present used. The only important place where it could not certainly pretty well displace coal would be in seagoing vessels, for they can not now, and probably never will be able to, navigate the ocean on the trolley principle, and it has to be said that it looks more like the job

of a century than of a decade to get the storage battery in shape for transatlantic working.

But the railways would all be run by it, and arc and incandescent lamps would shine on the country roads and in rural hamlets all along the distributing lines in the kingdom. The reign of electricity would have set in, for Great Britain at least, in a sense not realized at all as yet, though we speak of the present as the age of electricity; and the deadly smoke from London, Manchester, and Liverpool chimneys would cease, with its accompanying black and yellow fogs and consequent stagnation of business and various kinds of illness. St. Paul's could be cleaned up once for all and shine forth in its whiteness for generations, instead of becoming again the grimy and disreputable-looking object that the soot from London's bituminous coal has made it.

It is hardly to be expected that the great work referred to will actually be begun just yet, although it would be little more than an even thing between the cost of this fifteen-mile dam and Manchester's thirty-five-mile ship canal, but it is one of the great projects that the near future is likely to have in store, and all the results I have foreshadowed are logical outcomes of it. The length of time that the construction of such a work would require has been estimated at in the vicinity of three years, if properly pushed, and the cost would probably be something over one hundred million dollars.

Considering the thing from the broad standpoint of the change in the whole geography of the British Isles which would follow the construction of the isthmus, several most interesting and extremely important questions arise. As to whether these have been all carefully investigated by the projectors of the proposed enterprise I am not aware. In the first place, what would become of the water which at present finds a vent through the Irish Channel in case this channel were stopped? It would presumably go by the west coast of Ireland and a small part, perhaps, up round by the north and east of Scotland; and the question is, would this have a salutary effect upon the west Irish coast, and would it withdraw a part of the Gulf Stream's benign influence from England and the east coast of Ireland? The result of the work might possibly show it to have been unwise to tamper with the natural course of a main branch of that ocean current which is known to have such an excellent influence on the climate and temperature of the British Isles, which, as everybody knows, are as far north as Labrador. The possibility reminds one of the story of the Anglophobiac American who proposed cutting a canal through Yucatan, or some such locality, in order that the Gulf Stream might be nipped in the bud, so to speak, and never reach England

at all—thus turning, as he expected, that island into an abode of arctic snow and ice.

Another feature of the case is the fact that the daily tides would not be the same on the two sides of the dam. To the north one could look clear out to sea over the Atlantic Ocean; to the south is about three hundred miles of practically inland water before one gets out to the open ocean coast. The tides on the open coast are about the same height and come at about the same times south and north; and at present, at any given point in the Irish Sea, the height of the sea level at any time is determined by the resultant of the tides from the north and south respectively. The construction of a dam at the northern entrance would leave the whole Irish Sea subject only to the influence of the tides from the south, while on the north side of the dam the tide level would be the same as that of other points on the open coast. Since, now, it would take some time, probably several hours, for the effect of the southern tide to reach the south side of the dam, the tides on the two sides would be anything but synchronous. When the tide was at its height at the north side it would be, perhaps, half-way up on the south, and would be high on the south by the time a considerable recession had taken place on the north. This variation would have a most important bearing on the working of the power machinery at the dam, because, instead of the difference of level between the water on the two sides being constant, and giving therefore a constant pressure, it would vary so as to be at times greater and at times less than would be the case if the effect alluded to did not take place. In order, therefore, to supply an equable driving head to the dynamos, the turbine wheels would have to be powerful enough to work up to the required capacity on the minimum difference of level. Since the power made available by the dam would be remarkable for the vast volume of water to be drawn on, rather than for great difference of level, the interference of the tides in at times reducing this difference perhaps considerably would be a matter of grave inconvenience in the way of the successful operating of the power generators.

THE system of school education, though judiciously criticised, is not regarded in the paper of Prof. Glynn, of Liverpool, on excessive mental work and some of its consequences, as being in a marked degree accountable for nervous overstrain in childhood. The tendency to this effect is considered to be in a great measure counteracted by the attention given to physical education and by the mental elasticity natural to youth. More serious are the consequences entailed by close and anxious application to duty of teachers and older students. As concerns the adult population, the injurious influence of overstrain is most active in towns, where the tension in the struggle for existence is greater and is associated with a desire too easily gratified.

RAIN-MAKING.*

By FERNANDO SANFORD,
PROFESSOR OF PHYSICS, LELAND STANFORD JUNIOR UNIVERSITY.

I SHALL ask your attention this evening to the scientific principles which are involved in the condensation of atmospheric vapor, and to some of the attempts which have been made to produce this condensation by artificial means.

Since the change from atmospheric vapor to water involves a change of the physical state of the same substance from a gas to a liquid, it is important that we understand clearly the difference between these two physical states.

Both liquids and gases are undoubtedly made of very small particles called molecules. In a gas these molecules are not held together by any force, but each molecule is a perfectly independent body, free to move in any direction without reference to any other molecule, except as its motion may be interfered with by colliding with another. Under all known conditions these gaseous molecules are actually in rapid motion, each one moving at its own rate and in its own path, unaffected by any known force except gravitation. Each molecule will, accordingly, move in a straight line until it collides with another molecule. When two molecules collide, their direction of motion will be changed according to the angle of collision, but on account of their high elasticity they rebound with the same force with which they collide, and the sum of their motions will be practically the same as before. Hence, no number of collisions between the molecules themselves will ever bring them to rest.

If confined within solid walls, they strike against these walls and rebound from them just as they do from each other. In doing so each molecule exerts a pressure upon the wall during its time of contact, and the sum of these pressures is the whole pressure of the gas upon the walls of its containing vessel.

These walls are likewise composed of similar molecules, but held together by some unknown force, and it is the surface layer of these molecules which must bear the shock of the molecular bombardment of the gas. Accordingly, the molecules of the solid walls, while not free to be driven about from one place to another, like the gaseous molecules, are nevertheless set in vibration; and since they can not lie as close together while in vibration as they could at rest, the solid mass of the walls is made to expand. By measuring the amount of this expansion we can de-

* A lecture given before the students of the Leland Stanford Junior University, March 6, 1894.

termine the energy of the molecular bombardment. By letting the vibrating molecules of the solid or the gas come in contact with the parts of our skin to which certain special sense nerves are distributed, we feel the sensation of heat, and we are accustomed to say that the expansion of the solid or the gas is due to heat. The total measure of the energy which any mass of matter has on account of the motion of its molecules is determined by the amount of heat—i. e., molecular motion—which it must give to other bodies before its molecules can come to rest. The higher the temperature of the mass—the more heat or the more molecular motion it has.

The atmosphere is, in general, made up of two different kinds of molecules. These molecules are, of course, very small—so small that no possible magnifying power can ever bring them into view. Their size is, in fact, so small as compared with the length of a light-wave that no image of one could be produced by reflected light. Still, there are several independent methods of calculating their approximate size, and, since these different methods lead to fairly accordant results, we may assume that their approximate size is known. According to Lord Kelvin's computation, if a drop of water were magnified to the size of the earth its molecules would become larger than shot and smaller than cricket balls, perhaps about the size of marbles. They are so close together in the air that the number in a cubic inch is represented by the number ten raised to the twenty-third power. Being so close together, and being at the same time in rapid motion, they must have frequent collisions, and, according to Maxwell's calculation, a molecule of air at ordinary temperatures would have seven or eight hundred thousand millions of collisions in a second of time. While these figures, both for size and number, can convey no definite meaning to us, they may aid us in picturing to ourselves the tremendous agitation which is constantly going on within our atmosphere or within the mass of any other gas.

Within the body of a liquid the conditions are similar, except that here the molecules are so close together that they can not be said to have any free path at all, and are, accordingly, in a state of perpetual collision. They are not, as in a solid, held to any definite position with reference to the surrounding molecules, but are hindered by a force called cohesion or capillarity from escaping from the liquid altogether. What the nature of this force is is not known, but it is evidently a pressure of some kind exerted upon the molecules tending to push them closer together.

Notwithstanding this force, the molecules of the liquid are in rapid vibration, and at the free surface of the liquid they are being continually bumped off by the molecules below them. When

this happens they become free gaseous molecules, and move off in straight lines under the impulse of the force which set them free until they come into collision with other molecules.

At the surface of separation between water and air the conditions are accordingly as follows: The surface layer of water molecules is held down by the force called cohesion, but the individual molecules of this layer are being continually bumped off by the vibrations of the molecules below them. Some of these free molecules are undoubtedly driven back by the bombardment of the air molecules above them, so that they escape much more slowly into the air than they do into a vacuum, but those which once escape into the air are knocked about by the air molecules and by each other until they are pretty evenly distributed throughout the air. After a time they become so numerous in the space above the water that, in their irregular excursions between their collisions with other molecules, they begin to strike the surface of the water, and then, under favorable conditions, they penetrate into the liquid and are held fast. This process continues until finally as many molecules enter the water as escape from its surface, and then, while a constant exchange is taking place between the liquid and gaseous molecules, the average number in the space above the liquid remains constant. This space is then said to be saturated with vapor molecules. The number of molecules required to saturate this space is the same whether the space already contains air molecules or not, but, on account of the number of water molecules which are beaten back by the air molecules, it takes much longer for the space to become saturated when it is already filled with air than it does when there are no other molecules in it. The air molecules, however, hinder the vapor molecules from striking the surface of the water as often as they prevent them from leaving the surface, so they do not influence the total number required to produce saturation.

When the point of saturation has been reached, an increase of temperature—i. e., an increase of the molecular vibration of the water—causes the molecules to be driven off faster than before. It also causes the gaseous molecules to strike the surface of the water oftener than before. But an increase of temperature means a corresponding increase of vibration of all the molecules; and, since there are very many more liquid than gaseous molecules in the same volume, the total increase of molecular vibration corresponding to a given rise of temperature will be much greater for the liquid than for the gas, and a correspondingly greater number of molecules will be thrown off at the surface of the liquid than will be returned to it. Accordingly, the higher the temperature, the more molecules are required to saturate the space above the water. In fact, the amount of water vapor required to pro-

duce saturation of the atmosphere under the conditions above mentioned is more than twice as great at 80° F. as at 50° F.

On the other hand, lowering the temperature of the liquid and vapor by a like amount lessens the number of molecules given off from the liquid surface more rapidly than it lessens the number striking upon the surface. Accordingly, we say that raising the temperature increases evaporation; lowering the temperature increases condensation.

Now, it happens that this same force of cohesion may hold water molecules upon the surface of most solid bodies as strongly as upon the surface of water itself, and in many cases even more strongly. Accordingly, if a solid body of this kind be placed in the atmosphere, the same exchange of water molecules will take place between its surface and the air as between a water surface and the air. In fact, as soon as a layer of water molecules is formed over its surface, it becomes a water surface. Accordingly, if a solid particle be placed in an atmosphere saturated with water vapor and the temperature be lowered, the water molecules will accumulate upon its surface faster than they are driven off, and we say that a precipitation of dew is taking place upon it. The air is accordingly said to reach its dew point when it reaches its point of saturation.

There are other substances which hold fast in a different way the water molecules which strike upon their surface. These substances form either chemical compounds or solutions with water, and in this way remove the water molecules from the places where they strike to the interior of the compound or the solution. Sulphuric acid is a good example of this class of substances. If a vessel of sulphuric acid be placed in a receiver filled with water vapor, the acid holds fast all the water molecules which strike its surface, and sends off no other water molecules to replace them. Since all the water molecules in the receiver will in time come in contact with the acid surface, they will ultimately all be held in a liquid form by the acid. Accordingly, a receiver of moist air can be changed to dry air by allowing it to stand for a sufficient length of time over sulphuric acid.

There are very many other substances which, like sulphuric acid, have the property of condensing the water molecules from a space which is not saturated with them. Such substances are said to be deliquescent, or to gather moisture from the air. Common salt and caustic potash are good examples of deliquescent substances.

There is still another method of producing condensation. If an inclosed space contain water vapor enough to bring it to the point of saturation, and if the volume of the space be decreased without changing the temperature, more molecules will strike

upon a given surface of the containing walls than when the volume of the gas was greater. Since the temperature remains the same, the same number of molecules will be driven off from a given surface of these walls as before. There will, accordingly, be a condensation upon the walls, which will continue until enough gaseous molecules have been removed to make the exchange again even.

These are the three known methods of changing water vapor to the liquid form—viz., by lowering the temperature of the vapor and the other bodies in contact with it until the point of saturation has been passed, by compressing the vapor until there are enough molecules in unit volume to produce saturation, and by allowing the vapor molecules to strike upon some surface which will immediately take them into solution or into chemical combination. I know of no other method by which water vapor, or any other vapor, can be changed into the liquid form.

The conditions necessary for the precipitation of the aqueous vapor from the atmosphere are, then, as follows:

(1) The air must contain enough molecules of water vapor to more than saturate it, and must contain at the same time either solid or liquid bodies upon which these vapor molecules may be held fast by cohesion; or (2) the air which does not contain enough water vapor to saturate it may come in contact with solid or liquid substances, which combine with or dissolve the water molecules which strike upon them.

This latter condition can manifestly play no important part in atmospheric precipitation. The only condition under which such substances could cause condensation above the earth's surface would necessitate their distribution throughout the atmosphere, and if they were so distributed they would constantly absorb the atmospheric vapor until, loaded down with it, they would sink to the earth, and there would be a condition of perpetual rainfall.

For the general precipitation of atmospheric vapor we must accordingly depend upon the condensation due to cohesion. Of this form of condensation, dew is the simplest illustration. During the day the earth and the solid bodies upon its surface are raised by the sun's radiation to a temperature higher than that of the surrounding air. So long as this is the case the atmospheric vapor will not condense upon them, even if the air be cooled to the point of saturation. In the night the same substances which absorbed the sun's heat fastest now radiate it fastest and soon become colder than the surrounding air. As soon as they are cooled to the temperature of saturation of the surrounding air the vapor molecules begin to condense upon their surface.

Now, the condensation of water vapor in the air above the sur-

face of the earth is dependent upon exactly the same conditions as the formation of dew. It used to be thought that, as soon as the air was cooled to or below the dew point, the molecules of water vapor in the air would come together and form drops of water. In 1880 Mr. John Aitken, of Scotland, began a long and very thorough series of experiments upon the condensation of water vapor from the air, and the same line of experimentation has been carried still further by Robert von Helmholtz and by Richarz in Germany. These experiments have all shown that vapor condensation within the body of the air only takes place upon the surface of dust particles which are floating in the air. Indeed, Robert von Helmholtz found that when the air was carefully freed from dust particles it could be cooled until it contained ten times the amount of vapor necessary to saturate it without any condensation taking place within the body of the air. Aitken thought that he had found one exception to this, and that in the case of a sudden shock upon the walls of the containing vessel, when the air within was oversaturated, precipitation would take place; but Robert von Helmholtz found that this apparent exception was due to the dust particles given off by the walls of the vessel at the time of the shock. Since this fact has been experimentally established, Lord Kelvin has shown mathematically that, from the known laws of surface tension in water, it would be impossible for a globe of water consisting of only a small number of molecules to hold together at all. The same calculation has been made by Robert von Helmholtz by means of a formula developed by his illustrious father. According to these calculations, the smallest sphere of water which could hold together at 0° C. would be ·00015 millimetre or ·000006 inch in diameter. Since this is 7,500 times the diameter of a water molecule as computed by Lord Kelvin, the smallest drop of water which could be held together by cohesion at this temperature would contain not less than four million millions of water molecules. At 40° the smallest possible water sphere would have a diameter about twice as great, and would accordingly contain eight times as many molecules.

Aitken found that dust particles of microscopic size were sufficient for the nuclei of condensation, and R. von Helmholtz showed that condensation could take place upon particles so small that it took four days for them all to settle through still air to the lower side of a horizontal glass tube about one inch in diameter.

Aitken counted the number of these dust particles in different samples of air by first diluting the air with two hundred times its volume of air which had had its dust particles removed by being drawn through water, and then saturating the air with water and cooling far below its dew point, and counting the number of

water drops falling upon a given area until all the dust particles were carried down. He found the number of dust particles to vary from 34,000 per cubic inch in pure air taken from the top of Ben Nevis to 88,346,000 per cubic inch in air taken from a room near the ceiling, and nearly 500,000,000 per cubic inch in the flame of a Bunsen burner.

The number of these dust particles in the air determines the character of the precipitation. If the dust particles are very numerous, each one becomes a nucleus for the condensation of water vapor, but only a small quantity of water will be condensed upon each one; hence the formation of the fine drops which constitute fog. If the number is smaller, as it is likely to be at a greater distance above the earth, each nucleus may receive a larger quantity of water, and a cloud may be formed. If they are few, or if the total amount of condensation is great, the drops which are formed become heavy enough to fall to the ground, and rain is produced. If the nuclei are very few, rain may fall from an almost cloudless sky.

It is well known that as we ascend above the earth the temperature falls about one degree Fahrenheit for three hundred feet; consequently, while the air at the surface of the earth may be far above the dew point, the air at a few thousand feet above the earth may be cooled below the dew point. The height of the clouds always indicates the distance above the earth at which the air is cold enough for condensation to begin. The clouds, being made up of these little dust particles surrounded by water, are heavier than the air, and are slowly settling toward the earth, but as fast as the little drops settle into the warmer air, the rate of evaporation from their surface is increased, and before they have settled far the water has been evaporated off. Hence, at a given time, over an area of uniform temperature, the lower surfaces of the clouds are all at nearly the same distance above the earth.

How, then, shall rain be produced in the great unbounded atmosphere? There are but two ways. Either the total quantity of vapor in the atmosphere must be increased, or the temperature of the air must be diminished. It is probably safe to assume that there are, under all ordinary circumstances, a sufficient number of dust particles in the air to form the nuclei for condensation, so that no artificial provision need be made for these.

So far as I am aware, no enterprising rain-maker has yet proposed a method of increasing the total moisture of the air to any appreciable extent, though some of them have attempted this on the small scale, probably in the vain hope that if they touched the button Nature would do the rest. This, by the way, has been the one claim upon which all these pretenders have based their arguments. They have steadfastly and with unanimity asserted

that if a little condensation could be started in one place it would at once spread out in all directions, like the benign influence of the little homœopathic pill. How a rainfall started in this way is ever to stop as long as any aqueous vapor remains in the air, they have not condescended to tell us. This question has not, so far as I know, ever been raised by the results of their incantations.

As a matter of fact, every drop of water taken from the air decreases the number of vapor molecules remaining, and, consequently, lowers the temperature of the dew point. Likewise, every free molecule which is brought to rest by striking against a solid body, gives up its energy of motion to that body and increases the total energy of its molecular vibration, so that a body upon which water molecules are condensing is having its temperature continually raised, and it must be continually giving off heat to surrounding bodies, or it will soon be warmed above the temperature of condensation. In the case of the dust particles of the atmosphere, they must give off this acquired heat to the molecules of the air which come in contact with them; hence the condensation of moisture from the air raises the temperature of the air. There are, accordingly, two reasons why heat must be continually taken from the air in order to keep up condensation. The temperature of the dew point is being continually lowered by the loss of vapor molecules, and the temperature of the air is being continually raised by the amount of heat which these molecules lose when their motion is stopped.

In the formation of rain by natural causes this continuous decrease of temperature is provided by ascending currents of air which carry the water molecules upward into continually cooler and cooler regions. These ascending currents of air may be caused by mountain ranges which deflect upward the winds that blow against them, by the expansion of the air over a heated area of the earth's surface, and possibly by other agencies not yet understood. In the case of our California storms, these ascending currents are usually persistent for several days, frequently moving across the whole continent. They are marked upon our weather maps as areas of low barometric pressure. Whenever there is an area over which the barometric pressure is less than the normal, it is an indication of an ascending current of air, and wherever there is an ascending current of air there is a probability of rainfall, though if the air be very dry it may not be carried to a sufficient height to be cooled below its dew point.

On the other hand, wherever there is an area of increased barometric pressure, or of high barometer, it is an indication that there is a descending current of air over that area; and since air which is settling toward the earth is continually having its temperature

raised, no precipitation of moisture will occur over an area of high barometer.

The simultaneous weather observations conducted by the Government enable us to locate these regions of ascending and descending currents, and long observation has enabled us to predict their probable path across the continent, and it is upon these data that the weather officers base their predictions of future weather. Since these areas regularly travel from west to east, we in California receive much shorter notice of their coming than do the people farther east, and the weather predictions issued from our local bureau are proportionally more liable to error than are those issued from stations beyond the mountains.

And now as to the possibility of producing rain by artificial means. It is never safe to say what things are possible and what things are impossible to man. What the future may bring forth no one can tell. At the present time, however, there is no evidence to show that even the smallest local shower has been produced artificially. Further than that it is safe to say that no method of producing artificial rain has yet been publicly proposed which suggests to one familiar with the scientific principles involved even a possibility of success. That such attempts have received the official recognition and the financial support of Congress is only another evidence of the gross ignorance of scientific principles which is prevalent among our so-called educated men. That some of the men who advocate these wild schemes are honest in their motives can not be questioned, but that all the professional rain-makers are conscienceless fakirs is scarcely more questionable. That many of them are able to submit testimony as to the efficacy of their system is equally true of every patent-medicine fraud and electric-healing quack who has ever swindled an ignorant public. As an illustration of the value of testimony of this kind let me give you a local example.

I will read from the San Francisco Examiner of February 2, 1894:

HE PRODUCES RAIN AT WILL.

HIGHLY SUCCESSFUL EXPERIMENTS OF THE VISALIA RAIN-MAKER.

HEAVY SHOWERS AT PIXLEY.

HE SELECTS THE DRIEST SECTION OF FRESNO COUNTY, WHERE RAIN SELDOM FALLS, AND BY THE USE OF CHEMICALS CAUSES LOCAL DOWNPOURS ON TWO SUCCESSIVE DAYS.—MANY OTHER TESTS MADE.

VISALIA, February 1st.—A week ago Wednesday Frank Baker, of Visalia, an amateur rain-maker, went to Pixley for the purpose of producing rain. Before he left he informed the Examiner correspondent that he intended to produce rain within seven days, and he kept his word. On Tuesday and Wednesday a local rainstorm occurred in the vicinity of Pixley amounting to 0·35 to 0·45 of an inch.

Mr. Baker returned to this city this morning in jubilant spirits. He is now satisfied beyond a doubt that he can produce rain by means of his appliance. He proposes to visit Pixley every two weeks, and is sanguine that he will be successful in his experiments.

During the months of April and May he proposes to put forth his best efforts in order to thoroughly drench the soil. The residents of Pixley are well pleased with Baker's experiments, and they propose to assist him in conducting his future operations.

THEY VOUCH FOR HIS EFFICIENCY.

He brought back with him the following letter:

"This is to certify that it rained 0·35 to 0·45 of an inch at Pixley on the 30th and 31st of January. We gentlemen here vouch for the truth of the same; that it is a local rain of fifteen to twenty miles in extent, and that it was brought about by the Baker process.

"J. J. KELLY,	L. E. SMITH,
"CHARLES S. PECK,	J. T. AUSTIN,
"W. M. JACKIN,	JOHN W. HARPER."

Now, it is not my purpose to impugn the veracity of the gentlemen whose names are signed to this certificate. I know none of the gentlemen. I do not question the only point in the statement to which the gentlemen could possibly subscribe of their own knowledge. You will observe that the certificate includes three separate statements: (1) That it rained in Pixley on the 30th and 31st of January; (2) that it was a local rain of fifteen to twenty miles in extent; (3) that it was brought about by the Baker process. Manifestly, the only one of these statements to which the gentlemen could have subscribed of their own knowledge is the first.

Fortunately for the settlement of questions of this character, we have the use of data collected by the Weather Bureau. When I read the above article I at once wrote to Mr. Pague for the maps issued by the Weather Bureau for January 28th to 31st inclusive. He kindly forwarded them to me, and the following data were compiled by me from them:

On the map of Sunday, January 28th, 5 P. M., an area of low barometer is shown with its center west of Vancouver. The weather was reported cloudy and rainy north of the Oregon line. The weather forecast was "Rain in northern California." Twelve hours later, Monday, January 29th, at 5 A. M., the storm was central over northwestern Washington. I quote verbatim from the predictions printed upon the map: "The conditions this morning are favorable for rain over California from the Tehachapi Mountains northward by Tuesday morning, and possibly will extend southward Tuesday afternoon or night."

At 5 P. M. of the same day the map shows a storm area extending from British Columbia to southeastern California, with its

center near Keeler, about ninety miles east of Pixley. Here the storm center remained for thirty-six hours, while the storm was gradually breaking up over its northern part, as shown by the three following maps, and not until the map of Wednesday morning is there an indication of an eastward movement of the storm, while as late as 5 P. M. of Wednesday, January 31st, rain was reported at Keeler. During Monday and Tuesday light rains were reported over nearly all parts of the State, and on Tuesday it rained at Pixley.

From these data we see that the local rainfall produced by the Baker process at Pixley was part of a storm which extended over a large part of British Columbia, over Washington, Oregon, California, Utah, Nevada, and Arizona, and which had its center for thirty-six hours within ninety miles of Pixley, and that the weather forecasts sent out from San Francisco on Monday morning at five o'clock predicted rain for the region about Pixley for Tuesday afternoon or night. As a matter of fact, it rained at Pixley on Tuesday night, as had been predicted by Mr. Pague thirty-six hours before.

I have referred to this special case, not because it differs in any essential particular from other well-authenticated cases, but because one typical example which any one can verify is worth a great amount of generalizing, and because this particular instance has been so prominently mentioned by the press of the State.

And now I wish to say a few words about the methods of some of the best known of the professional "rain-makers." For most of the following data I am indebted to a paper read by Prof. Alexander Macfarlane, of the University of Texas, before the Texas Academy of Science.

POWERS.—In 1870 Mr. Edward Powers, of Delavan, Wis., published a collection of statistics in a volume entitled War and the Weather. By means of these statistics he seeks to establish the remarkable fact that battles are followed by rain. He does not prove that battles are necessarily accompanied by rain, or that a day of battle is followed more quickly by rain than a day of no battle. Having, however, apparently convinced himself of the value of his argument, he at once adopted the universal American expedient of proving his claim, and petitioned Congress for an appropriation to make a suitable test. Two hundred siege guns which lie idle at the Rock Island Arsenal were to be taken to a suitable locality in the West, and one hundred rounds to be fired from them in each of two tests. The estimated cost of the experiment was to be one hundred and sixty-one thousand dollars. He does not tell us how the molecular vibration caused by the sound and heat of the firing is to lessen the molecular vibration of the air and cause the vapor molecules to come to rest.

Probably the distinction between a scientist and a crank could not be shown more clearly than in a comparison of the methods of Aitken and Von Helmholtz with the methods of Powers. The former spent years working in private and at their own expense to find if possible some explanation of the mystery of condensation. The other wished an appropriation of one hundred and sixty thousand dollars from the Government in order to test his visionary hypothesis.

RUGGLES.—In 1880 Daniel Ruggles, of Fredericksburg, Va., patented a process for producing rain. The invention, as described by Mr. Ruggles, consists of "a balloon carrying torpedoes and cartridges charged with such explosives as nitroglycerin, dynamite, gun cotton, gunpowder, or fulminates, and connecting the balloon with an electrical apparatus for exploding the cartridges."

This is another scheme for lowering the temperature of the air by heating it.

DYRENFORTH.—It is probable that the name of Mr. Dyrenforth is better known in connection with attempts at artificial rain-making than that of any other man. As a result of the agitation of Mr. Powers, Congress voted two thousand dollars to make a preliminary test, and the inquiry fell to the scientists connected with the Department of Agriculture. They reported that there was no foundation for the opinion that days of battle were followed by rain any more than days of no battle. It was then that Mr. Dyrenforth came forward with Ruggles's plans and offered to make some tests. Through the influence of Senator Farwell, an additional appropriation of seven thousand dollars was placed at his disposal for a series of practical tests, which were made at Midland, Texas, in August, 1891. A further Government appropriation was expended in tests at San Antonio, Texas, in November, 1892.

Mr. Dyrenforth's plan seems to have been to imitate as nearly as possible the conditions of a battle. His explosives were ranged in a line facing the advancing clouds. Shells were fired into the air at frequent intervals. Dr. Macfarlane states that the "general" and his lieutenant even wore cavalry boots.

In addition to these warlike demonstrations, cheap balloons containing hydrogen and oxygen mixed in the proper proportions for forming water were sent up, and the gases were exploded by means of a time fuse attached to the balloon.

At the time of making the San Antonio tests, November 25, 1892, the record of the weather office in San Antonio at 8 P. M. gave the temperature of the air at 72° F. and the temperature of the dew point as 61° F. Dr. Macfarlane makes the following calculations upon a cubic mile of the air under the above con-

ditions: To cool down the cubic mile of air to the dew point would require the abstraction of as much heat as would raise eighty-eight thousand tons of water from the freezing to the boiling point. To cool it eleven degrees more would require the abstraction of the same quantity of heat again. This would cause the precipitation of twenty thousand tons of water, which, spread over a square mile, would give 1·4 pound per square foot or 0·27 of an inch of rain. The amount of heat which the twenty thousand tons of water vapor would give off to the particles upon which it would condense would raise a hundred thousand tons of water from the freezing to the boiling point, and this would also have to be taken from the air in order to allow the condensation to continue. According to this computation, enough heat would have to be extracted from the air to raise two hundred and seventy-six thousand tons of water from the freezing to the boiling point in order to produce a rainfall of about a quarter of an inch over an area of a square mile. This two hundred and seventy-six thousand tons of water would cover the same area to a depth of more than six inches. Accordingly, in order to produce a rainfall of a quarter of an inch under the conditions mentioned, enough heat would have to be taken from the air to heat a body of water covering the whole area to a depth of ninety feet through one degree Fahrenheit.

To accomplish this purpose Mr. Dyrenforth proceeded to raise the temperature of the air still higher by means of heat-producing explosives.

Under these conditions eight balloons, a hundred and fifty shells, and four thousand pounds of rosellite were fired off. No rain appeared. One balloon exploded within a black rain cloud, but failed to produce any precipitation. On the following Wednesday, with a clear sky, ten balloons, a hundred and seventy-five shells, and five thousand pounds of rosellite were exploded, and the sky remained clear. On the following night the remaining stock of explosives were fired off, regardless of consequences, to get rid of them.

At the time of this national *fiasco*, another patented plan of rain-making was published, and it was reported that Senator Farwell liked it even better than the concussion plan. It proposes to send up liquefied carbonic acid and to set it free in the portion of air from which it is desired to precipitate the rain. The carbonic acid in vaporizing and expanding must take heat from the surrounding air sufficient to set its molecules vibrating in the gaseous form. Unquestionably we have here the proper kind of an agent for producing rain. The only question to be considered is one of finance. Prof. Macfarlane estimates that one pound of carbonic acid in taking the gaseous form at 72° F. would take up

enough heat to change sixty-eight pounds of water by one degree Centigrade. To cool the cubic mile of air formerly considered sufficiently to make a rainfall of a quarter of an inch would accordingly take four hundred and six million pounds of carbonic acid. This could probably be purchased in quantities of this magnitude at one dollar a pound, making the expense of a rainfall of a quarter of an inch, not counting anything but the carbonic acid, about six hundred thousand dollars per acre. This would make artificial climate even more expensive than the genuine California article.

I have now endeavored to give you in as brief a space as possible a simple statement of the problem of rain-making as it appears to one with an elementary knowledge of physics, and to give a brief statement of some of the methods of the men who, without any scientific knowledge, have intentionally or unintentionally imposed upon the public. The examples which I have quoted are only the prominent ones. There are many impostors whose names are but little known who are proposing to furnish rain to large sections of country for a suitable financial consideration. And it is only surprising that the number is not larger. The business offers special inducements to men who are accustomed to make a living by swindling their fellow-men. No capital and no business training is required. The only thing necessary is to contract to furnish rain to as many different sections of country as possible. Then, if it rains over any of these areas, collect the pay. If it does not rain, the experiment has cost nothing. The system has all the advantages of the traditional gun loaded to kill if it is a deer, but to miss if it is a calf.

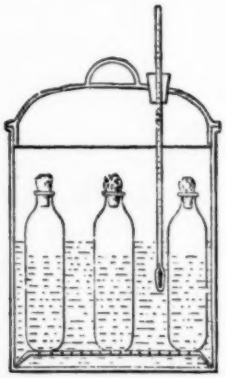
MILK FOR BABES.

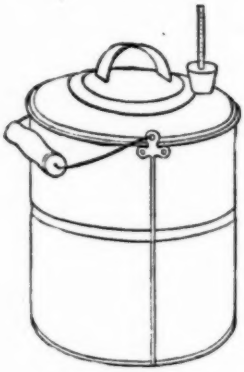
By Mrs. LOUISE E. HOGAN.

IN the natural advance made in the study of the subject of infant foods—methods of preparation, administration, etc.—the process of sterilization of milk, as ordinarily and formerly understood, is now replaced by "Pasteurization," which is, practically speaking, the low-temperature process of the earlier method, and specialists who comprehended the serious changes produced in milk by high and prolonged temperature advised from the first the lower method.

It is easy enough, by prolonged and repeated application of a high temperature, to keep milk apparently unchanged, but the point aimed at all along has been to devise a way by which it might be made sterile with the least possible interference with

its nutritive qualities. Investigation has demonstrated that milk subjected to lengthy boiling under pressure is in many ways unsuited to the digestion of an infant. Chemical analyses have proved what experience has shown to be the case—namely, that milk sterilized by the higher and prolonged temperature is not fit for administration to an infant. Dr. Henry Chapin, of New York, has been making a study of infant feeding and of children in the Post-graduate Hospital of that city, to which he is attached, and he says, in an article recently published in the New York Medical Journal, that partial sterilization or Pasteurization, to the point of killing the germs only, is necessary and desirable, as a high and continuous temperature produces unfavorable changes in the milk; the fat collects in masses, the albuminoids are changed, the casein is altered, and the digestive action on the casein of sterilized milk is incomplete. Simply





sufficient heat must be applied to the milk to keep it sweet until the next supply can be procured. Herein lay one of the most frequent sources of trouble in the earlier days of sterilization, caused by lack of exact knowledge in this direction; and in addition to this, when sterilized milk was first introduced, many mothers reasoned that, being sterile, it was a perfect food, and consequently used it without any further preparation, with the natural result of indigestion and all its resultant ailments. It is quite true that milk to be a perfect food must first be sterile, but it must also be assimilable; and to reach this point great care must be given as well to its preparation and administration. Notwithstanding the care exercised by boards of health, it is impossible at any time to be sure of the purity of the milk supply; hence the need is urgent that it be made safe by Pasteurization, which is, in reality, simply subjecting the milk to the lower temperature of 150° to 160° F., instead of 212° F., as was formerly done, and is called thus in deference to Pasteur, who long ago found that the ordinary germs of fermentation and bacteria

would be destroyed by this temperature, and recommended such a process for their destruction and for the preservation of foods. Thirty years ago Liebig said that by scalding milk once a day it could be kept indefinitely, and many a housewife, before and since, has put the same fact into practice. The process is new only in name—the discovery lies principally in its application—experiment having shown that the application of 150° F. for thirty minutes will destroy the *Bacillus tuberculosis* with certainty, and many germs that are likely to be found in reasonably pure milk, which, with ordinary precaution, will remain sweet for several days.

There is a good deal in a name, and it is to be hoped that "Pasteurized" milk will receive as cordial a welcome as was given to "sterilized" milk.

Generally, new ideas are received with some conservatism and are subjected to tests in expert hands before being adopted by the public; but the need was great, and it is seldom indeed that anything has had the benefit of so wide a trial and so immediate an acceptance as this idea of sterilization of milk. Benevolent persons opened dispensaries to give it to the poor, who, jumping to the conclusion that it was "exactly like mothers' milk" and had wondrously valuable qualities, failed frequently to see the true purpose of the work. Few stopped to inquire what sterilized milk really was, and directions given for its use were rarely followed.

The fact that milk, when subjected sufficiently to a high temperature, can be kept unchanged for an indefinite length of time, while of interest from a scientific standpoint, is of no practical interest to consumers, except upon long journeys, as it has been conclusively shown that for ordinary usage Pasteurization should be done daily. It is generally conceded that pure milk will save much infant mortality. The fact that thousands of children—especially infants—die every year from want of care in the preparation of their food is underestimated by many. At one of the meetings of the Philadelphia Board of Health, Dr. Shakespeare said, in his report, that milk of poor and unwholesome quality is originally and directly responsible for thousands of deaths annually in that city alone, not to speak of the sickness from this origin which is not fatal. To this category, he declares, certainly belong most deaths from cholera infantum, infantile tuberculosis, many of the deaths from acute diarrhœa, from typhoid fever, and some of the deaths from diphtheria and scarlet fever.

Dr. Chapin says that of six hundred infants whose cases were studied, nearly all the troubles were acquired and not hereditary. "While a tendency to constitutional disease may be inherited, it is the bad surroundings and faulty conditions of life that powerfully predispose to illness"—poverty and ignorance being the

chief sources of difficulty. He says the waste of child life in densely populated centers, especially in New York, is enormous. Last year the bodies of three thousand and forty-two children under five years of age were received at the morgue and nearly all were buried in Potter's Field, killed by poverty and ignorance, want of proper diet and care. In France, out of two hundred and fifty thousand infants dying annually, M. Rouchard, President of the Society for the Protection of Children, says one hundred thousand might be saved by careful nursing. This knowledge caused the passage of the bill forbidding the use of solid food for infants under one year of age, unless advised by a physician.

In the effort to guard against the tuberculosis germ our own Government is taking action, and the United States Department of Agriculture, in connection with work upon the forthcoming report upon tuberculosis, has issued a circular giving simple directions for the sterilization of milk. Dr. Salmon, in his report, comments upon the danger of contagion, and says the sterilization of milk can be satisfactorily accomplished by a very simple apparatus, which he describes at length. Any suitable utensil—whether a bottle plugged with cotton or a Soxhlet stopper, a fruit jar loosely covered, or whatever vessel may be used—is to be placed inside of a larger one of metal containing water, the requirements being that the interior vessel shall be raised above the bottom of the other, and that the water shall reach nearly or quite as high as the milk. The apparatus is then heated until the water reaches 155° F., when it is removed from the heat and kept tightly covered for half an hour. The cooling after this should be rapid, and the bottles kept in a low temperature. A hole may be punched in the cover of the pail, a cork inserted, and a chemical thermometer put through the cork, so that the bulb dips into the water, or a dairy thermometer may be used by removing the lid from time to time.

An ordinary double boiler will be found to meet all the requirements, using the dairy thermometer. If preferred, the Arnold steamer or the Freeman Pasteurizer will be found convenient. Dr. Chapin says that fifteen minutes' heating will be found sufficient, as a rule.

The problem seems to be, in infant dietetics, to approximate such milk to the composition of human milk. That this can be done has been demonstrated by expert analyses, results showing that the value of this care is not overestimated by those who thoroughly comprehend its purpose. The casein of the milk, being the objectionable feature for infant diet, must be treated in such a manner as to make it digestible, supplying at the same time the constituents required as a consequence of this treatment, by the addition of sugar and fat.

Clinical results point to barley water as the best diluent, as it produces the finest curd. As a result of Dr. Chapin's study and experiments made by Dr. Arnold Eiloart, a receipt has been devised by which a mixture of barley or wheat flour is treated with maltine, the effect of malt upon milk being to favor its digestion and assimilation. Dr. Judson C. Smith, who is a district visitor for the hospital mentioned, says he has used the extract of malt to peptonize milk for about a year, both for infants and adults, with very satisfactory results. His method has the advantage of simplicity. One tablespoonful of malt is added to a pint of milk, which is heated from twenty to thirty minutes and then brought to the boiling point, which practically Pasteurizes the milk. It is to be diluted for administration according to the age of the infant. Top milk should be used with the proportion of cream sufficient to give at least four per cent after dilution; thus, twelve per cent of cream would be required to allow for two parts of water to one of milk, which is the dilution advised by Dr. L. Emmett Holt in order to reduce the proteids to their normal proportion. By careful experiment he has found that one quart of ordinary cow's milk, allowed to stand for six hours in a common fruit or milk jar, will give about five ounces of top milk of this strength.

The underlying truth of all the past and present agitation concerning the purity of the milk supply and the artificial feeding of infants is that both have been sadly neglected for many years, with the pitiful result of a vast amount of suffering and many useless deaths of children from one to five years of age, especially during the hot summer months, when it is so difficult not only to secure but also to protect the milk upon which these little ones depend. Comparatively few people stop to consider how quickly dangerous changes take place in this important article of food and how readily it becomes contaminated by absorption of various volatile substances. This is particularly true of those who have the immediate charge of milk. It is appalling to any one understanding the subject and its bearings to see the carelessness that is frequently displayed by the milkmen, maids, and nurses, all of whom play so important a part in infant dietetics. Is it any wonder that philanthropists, scientists, and physicians have combined in solicitous effort to wake up mothers to the crying need for a pure supply of milk and for its proper administration to save helpless and suffering infants? The subject is of infinite importance, and should be kept constantly to the front. The truths concerning it should be iterated and reiterated until satisfactory evidence has been given that persistence in a cause like this has been of some avail in changing existing conditions that are a reproach to our people and a menace to our health as a nation.

NATURE AS DRAMA AND ENGINERY.

By GEORGE ILES.

PROF. EDWARD B. POULTON, of Oxford, in closing his course of lectures at Columbia College, last February, described the cordial reception extended him on his arrival in New York. Taking a stroll through Central Park, he had walked but a few paces when a gray squirrel ran from a tree to his feet in the friendliest way possible. "The perfect trustfulness of the little creature," said Prof. Poulton, "told me at once the most important fact of its life—that here in the midst of a teeming population it was certain of kind treatment. I inferred that a community kind to animals must be interested in them, must be fond of studying them in the very best place, their field of life." Nor was the naturalist disappointed; he found his New York audiences enthusiastic, and his lecture room, crowded to the door, contained less than half those who sought admission. Just as his observation of the squirrel in the act of soliciting luncheon told him what could never be disclosed in an inspection of the rodent, however skillfully stuffed in a museum or dissected in a laboratory, so, as the readers of his Colors of Animals well know, Prof. Poulton has discovered much of profound interest in natural history by keeping to the unfenced field so fruitfully scanned by the eye of Charles Darwin. Somewhat as in the case of his great master, his work owes its reward and derives its charm from its inclusive breadth of outlook. Specimens of hornet clear-wing moths might be collected for years, dissected under the microscope with the utmost care, and classified with the nicest precision, without casting a single ray of light on the prime questions, What forces have molded the form and habits of this insect, and why are its hues and markings as we find them? Let the moth, however, be observed in its field of life, and the agencies which have made it what it is come clearly into view. Among the insects which share its woods and meadows will be noticed a wasp; while this wasp neither preys upon the moth nor in any perceptible degree competes with it, the two insects sustain to each other a most vital relation. In its sting the wasp has so formidable and thoroughly advertised a weapon that by closely resembling the wasp the moth, though stingless, is able to live on its neighbor's reputation and escape attack from the birds and insects which otherwise would prey upon it. And so far is the mimicry carried that when the moth is caught in the hand it curves its body with an attitude so wasplike as seriously to strain the nerves of its captor. How came about so elaborate a piece of masquerade? At first, the explanation is, there was a faint gen-

eral resemblance between the moth and the wasp; any moth in which that resemblance was in any degree unusually marked had therein an advantage, and tended to be in some measure left alone by its enemies; in thus escaping it could transmit its peculiarities of form and hue to its progeny, and so on, until in the rapid succession of insect generations, amid the equally rapid destruction of comparatively unprotected moths, the present striking similarity was at last attained. The study of mimicry of this type has from an unexpected quarter afforded singular confirmation of the theory of natural selection; in many cases the evidence of transformation within comparatively recent time is distinct—in the bee hawk moth, for example, the wings as they emerge from the chrysalis are thinly clothed with scales of ancestral derivation which are shaken off in the insect's first flight, with the result that the bumblebee is the better and more gainfully resembled.

As in the study of insects, so in that of plants—observation in the field at every stage of growth and development is needful to supplement the disclosures of the microscope and the dissecting needle. Many species, of which the milkweed blossom may stand as a type, are absolutely dependent on insects for their fertilization. How, therefore, can they be fully known in the laboratory and the herbarium? There is no more remarkable adaptation in Nature than that by which an orchid and the insect which continues its race conform to the outlines of each other. And hundreds of flowers less conspicuous than this orchid present perfumes, colors, and mechanism for attracting, seizing, and even imprisoning their insect visitors, which might well be the work of deliberate contrivance instead of inevitable selection from varying scents, hues, and forms of those which prove slightly more serviceable than others. That clover, peas, and other legumes receive their nitrogen from the air has long been suspected by agricultural chemists. The details of the process disclose one of the most curious interdependencies in the realm of Nature. Prof. Hellriegel has discovered nodules on the rootlets of the plants, tenanted by parasitic bacteria, which, while consuming a little of the substance of the plant, pay a handsome rent in the compounds of nitrogen which they build out of the air and pass to the fibers that harbor them. These microscopic purveyors, when bred and sown of set purpose, yield vastly increased crops of clover, alfalfa, peas, cow peas, beans, and lupine. Of this abundant testimony was presented at the Columbian Exhibition in the display of the Experiment Stations in the Agricultural Building.

Here, indeed, we come to the distinctive standpoint whence knowledge sweeps its new horizons: its outlook upon Nature as a whole, as a system intelligible only in the mutual interaction of

its every part, however diverse and remote. It is a drama, not a tableau, which the observer to-day sees spread before him; in that drama every actor has been molded by the part it has had to play to maintain itself upon the stage; every rival, every parasite, every stress of climate with all its influence on food and frame has left its impress; and the ever-threatened doom for irresponsiveness has been the extinction pronounced upon countless forms once masters of the earth. No hue of feather or scale, no barb or horn, no curve of beak or note of song but has served a purpose in the plot or advanced the action in some life story of conflict. When Darwin was confronted in plant or beast by an organ which puzzled him, he was wont to ask, What use can this have had? And rarely was the question asked in vain. In the lunar or weekly recurrent periods of many animal functions there appeared to him a lingering registry of primordial birthplaces; ancestral inhabitants of seashores washed by tides being, in alternate submergence and exposure, profoundly affected in frame and habit.

What is true of the drama of organic life is equally true of the theater in which that drama is enacted. The more thorough its exploration by the geologist, the more extended in time the range of his admissible computations, the more convincing proof does he gather that our planet has become what it is in obedience to forces such as make the world at sunset a little different from the earth that faced the dawn. The hills once called eternal he knows to be anything but changeless, for their very prominence has made them special targets for the fury of tempests, the dividing axe of frost. At the bidding of impulses as irresistible, impulses hidden in the planet's core, a mountain is lifted in a valley's place, and the threatened denudation of a continent by the work of rain and river is silently compensated. And as Prof. Sterry Hunt was accustomed to point out, in the very constitution of the rocks before they bloomed with life, there was prefigured the struggle soon to be illustrated in plant and fish and insect. Amid the wealth of mineral compounds brought to birth only the stablest could survive the ceaseless stress of impinging forces. And these forces as they swept the lifeless globe—how decisive their after influence on herb, and beast, and man! Here, lifting the backbone of a continent, which all the storms of ages should leave a backbone still; there, in mid-ocean bidding an island rise from a volcano's heart; or decreeing a Sahara, or an Australian desert even more forbidding, where only cactus of the hardiest should ever fringe its dust-blown confines. In all this ever-shifting scene of action were laid the foundations of future barrenness of crag or fertility of plain, of that rich variety of earth sculpture in promontory and coast line which has meant so much to humankind.

In the history of the earth the chapter which precedes that written by the geologist is recited by the astronomer, whose key-note also is dynamic. The bulk, inclination, speed, and composition of the earth were all predetermined in the constitution, mass, and motion of the nebula which flung it forth. Dr. Huggins, his spectroscope before him, tells us that were the earth to resume a glowing heat it would yield much the same spectrum as the sun. Clearly, then, the scope of life on land and sea, the architecture of the forest, the ocean and the plain, with all their throbbing life, are what they are because the atoms which built them were present, and in such and such proportions, in the birth-cloud. If a blossom has tints of incomparable beauty, they are conferred by diverse elements thence derived, whose kin aflame in an orb, a celestial diameter away, send forth the beam needful to reveal that beauty. Were the sun less rich in variety of fuel than it is, the world, despite its own diversity of element, would be vastly less a feast for the eye than that which daily we enjoy.

As in the realm of organic life the modern interpretation is no longer static, so also in the sphere of Nature inorganic: it may be that all the thrust, recoil, and interaction in the life of plant and animal lay dormant in the simpler enginery of the atoms and molecules which build their frames and supply their food. It was one of the shrewd guesses of Sir Isaac Newton that the diamond is a combustible body; he did not suspect it to be one with coal in substance, but he observed it to be highly refrangible, as many combustible bodies are. His conjecture shows him to have taken the first step toward the view of modern physicists and chemists—namely, that properties, the modes of behavior of matter, are not passive qualities, but are due to very real activities; that what a substance is depends upon how in its ultimate parts it moves; just as organic structure can be deduced from living function because regarded as the creation of function, or, as in more familiar cases, the character of a die is inferred from its impress, and the construction of a machine read in the work it executes. Clausius and Maxwell, in a theory which marks an epoch, explained the elasticity of gases as manifesting the ceaseless motion of their molecules, declaring that an ounce of air within a fragile jar is able to sustain the pressure of the atmosphere around it, because the air, though only an ounce in weight, dashes against the containing walls with an impact forcible enough to balance the external pressure—proof whereof consists in measuring the velocity with which the air rushes into a vacuum. Here the significant point is that in leaving the realm of mass-mechanics, where the tax of friction is ever present and inexorable, we enter a sphere where motion of the swiftest can go on forever without paying friction the smallest levy. The elasticity of metallic springs has been

similarly explained as kinetic. If we swiftly turn a gyroscopic wheel we can only change its plane of rotation by expending force, which force is repaid when the metal is allowed to resume its original plane of motion. It is imagined that in like manner the particles in an elastic spring move swiftly in a definite plane; if deflected from that plane they oppose resistance and stand ready to do work in returning thereto. Of kindred to the kinetic theory of elasticity is the modern explanation that heat consists in a distinct and ceaseless molecular motion, on which motion, indeed, depend the dimensions of masses. Take a cube of lead or iron from summer air into an ice-house and at once the proportions of the mass begin to shrink. And the molecules themselves, whether of lead, iron, or other element, are imagined by Helmholtz as vortexes born of the ether in which without resistance they forever whirl. As observation proves in the case of a rapidly rotated chain, substantial rigidity can be conferred by motion sufficiently swift. Nor are molecules without something of individuality. We are wont to think of masses of solid iron as precisely similar, but experience proves that one bar or shaft of iron varies from another by all that has differenced the past history of the two. A careful workman uses his die of strongest steel for only a short term of service, well assured that the metal, despite its seeming wholeness, suffers serious internal shocks at every blow—shocks which, were no caution exercised, would soon reveal themselves in fracture and ruined work. In phenomena of this type, which every day confront the electrician and the engineer as well as the mechanic, there seems a prophecy of the sensibility and memory which dawn with organic life.

In the broad field of wave energy the mechanical analogies point to the sway of a single law of motion. If a pendulum is to be maintained in its vibrations, it must receive impulses sympathetically timed—impulses related to its own period of swing as decided by its length. In like manner a piano string vibrates responsively to the note which, when struck, it sends forth; and a gas, such as sodium, when comparatively cool, intercepts in the spectroscopic field precisely those waves which a glowing body of similar gas in the flame of sun or star has radiated. A pane of glass which transmits only the red rays of sunlight, when molten emits the rays complementary to red, and glows as greenish blue. Uncolored glass, which transmits light perfectly, conducts heat badly, because the vibrations are unlike; for the same reason conductors of electricity—the metals, for example—are opaque. The late Dr. Hertz, in generating electric waves intermediate in amplitude between those of sound and light, discovered that opaqueness is a relative term—arm a wave with appropriate dimensions and it has a passport through any substance whatever;

a stone wall or a wooden door becomes as permeable as plate glass to sunshine. All this has long been suspected by the physicists who, among equally significant facts, have noticed that an explosive is set off less by the violence of its detonator than by the sympathy of rhythm between the two. Dr. Lothar Meyer, in his Modern Theories of Chemistry, discusses the ingenious theories which on kinetic principles explain many of the chief qualities of matter—color, refrangibility, volatility, fusibility, and ability to yield heat in combustion. He regards this field as that which bears most promise for the chemical investigator, and follows Berthollet in maintaining that chemistry is but a branch of the larger science of mechanics. In corroboration of this view a thousand facts might be cited—a typical piece of evidence is that adduced by Mr. Witt, who finds that the stability of the azo-benzene dyes turns upon the nicety with which their acid and basic functions balance each other.

In leaving the field of molar for that of molecular mechanics, it has been already noted that friction need no longer be reckoned with; consequences equally important result from the fact that now masses of extreme minuteness are in play. Sir William Thomson (Nature, vol. i. p. 551) has estimated the diameter of molecules as at most $\frac{1}{100000000}$ of an inch in diameter; cubical molecules of this size containable in a cubic inch of space would have a total surface of one square mile and one seventh, which implies that in molecular mechanics superficial forces must count for vastly more than in molar mechanics. Another result follows from molecular minuteness of dimensions—an enormously increased capacity for motion. The smaller a wheel the more swiftly can it be rotated without being parted by centrifugal force, and therefore the more motion can it contain. With a molecule probably, with an atom certainly, centrifugal force has no separating power. How great the momentum of specific molecular motions will appear in computing that due to temperature, in the case of a pound of unfrozen water at the zero of the centigrade scale. According to the determinations of Lord Rayleigh, a pound of water, in falling through one degree of temperature, liberates heat equal to that generated were the mass to fall from a height of fourteen hundred and two feet to the surface of the earth. Therefore, in first becoming ice, and then falling in temperature through two hundred and seventy-three degrees, it parts with an amount of energy equal to lifting the pound of water some fifty-seven and one third miles from the surface of the earth, leaving out of view, for simplicity's sake, the diminution in the attraction of the earth as the mass is lifted. Prof. Dewar, in his recent remarkable experiments at a temperature of 200° below zero, has found reason to believe that at absolute zero the electri-

cal resistance of metals would disappear; cooled to the temperature of liquid oxygen, the red oxide of mercury becomes yellow, and both sulphur and bichromate of potash turn white.

Surprising as are the figures which denote the molecular motion due to the temperature of water, more surprising still are the computations which declare the chemical energy in the gases which unite to form water. Measuring the heat liberated in their union, it is found that the molecules of hydrogen and oxygen possess as chemic motion energy equal to lifting the masses involved some eleven hundred miles from the surface of the earth. It is imagined that the molecular motions representing temperature, chemical affinity, electrification, or other energy, coexist without confusion, just as air sustains, in perfect order, the superposed harmonies of an orchestra and chorus. The extremely rapid motion of molecules, acting at their comparatively vast surfaces, must immensely exalt forces which, between masses, are but feeble. A simple model may help to make this clear. Let two cylindrical wheels, similar in all respects and covered with rubber, be brought into contact on a floor—they will in a slight degree adhere; let the wheels be swiftly turned in a direction toward each other, and they will press each other with considerable force—force proportionate to their speed, which force at high speed will exalt their weak adhesion to somewhat of the intensity of cohesion as manifested between molecules. The model can illustrate something more: as a unit it does not change its place, albeit that its halves are in rapid motion; were its dimensions too small for microscopic view, the motion of its parts would be undetected, and, because the motions would balance each other, a mass built up of such pairs of molecules would be in seeming rest.

While the chemists are busy disentangling the orbits in which swim the atoms and molecules of the laboratory, the physicists are equally active in endeavoring to reduce to mechanics the various phases of energy. Here the first and decisive step was taken when the revelations of form and color to the eye were explained as borne by ethereal waves, which follow one another at a rate so prodigious as to yield the impression of rest; which explanation, indeed, had long been suggested in the phenomena of sound where air-waves are palpably concerned. The notable points of agreement in both spheres of action are that a medium can transfer motion as perfectly as if the two bodies connected by it were in immediate contact; moreover, that the efficiency of the medium increases as its density diminishes; and that the medium itself exacts no toll whatever, relapsing when its work is done into the seeming rest from which its task awakened it. With apparatus acoustic in model, the late Dr. Hertz, of Bonn,

demonstrated that light and electricity differ from each other only as short waves differ from long ones; presumably the same medium serving as the vehicle for both. His masterly experiments thus disclosed another bridge between modes of motion which less than a century ago were accounted distinct and unconnected.

While the establishment of the truth of the conservation of energy justly ranks among the grandest achievements of human thought, that truth would be rounded into satisfying completeness were it proved that energy in all its forms is motion and nothing else. The obstacle here is that gravity does not lend itself to any kinetic theory thus far framed. And this notwithstanding that atomic weight is the fundamental characteristic of matter, so that, indeed, it conditions every property of a substance—proof of which arrived in the fulfillment of the predictions of Mendelejeef, who, taking this theory as his finder-thought, foretold that scandium, gallium, and germanium would be added to the list of chemical elements, and would be found to possess properties which he detailed. Gravity is marked off from other phases of energy by two characteristics—if it be transmitted through space as are other modes of motion, it either travels instantaneously, or so fast as to elude the observation of astronomers competent to detect its movement were it fifty million times as swift as light. Quite as remarkable is the fact that a mass may be heated, electrified, magnetized, or chemically transformed without its weight being affected in the slightest degree. This in striking contrast with the action of heat, which modifies the color, chemical activity, conductivity, and other properties of a substance, and its volume as well. The only analogy which gravity bears to other forms of energy is that which it sustains to electricity and magnetism, and were these forces attractive only, the analogy would be a close one. But let us trace what analogy there is and we may find it helpful. In the manufacture of a common steel magnet the palpable motion of a dynamo disappears to create its attraction; the imparted dynamo-motion therefore is imagined as continuing in full actuality in the molecules of the magnet. When an armature is brought within the magnet's field it is attracted—that is, it powerfully tends to move toward the magnet; until that impulse is satisfied a space divides armature and magnet. All the analogies of light and electricity, proved to be fundamentally one with magnetism, bid us believe that between magnet and armature a medium is actively concerned in bringing both masses together; why may not a similar, or that identical, medium be active in bringing from a tree an apple to the earth? What is needed here is investigation of how the motion of a molecule in its own orbit, or on its axis, becomes

a movement of translation. A wheel, if frictionless like a molecule, could revolve on its bearings forever; if it were small enough, its motion would forever escape observation. Were it dropped from its bearings, through however short a distance, to a horizontal plane, part of its energy would be at once expressed in its advancing in a line long enough for detection. The question behind attraction and repulsion is, How shall two distant bodies move on their axes, or in their orbits, so as to act on a chain of intervening bodies with the effect that the two shall approach or recede from each other? This problem does not seem to present insuperable difficulty to the inventiveness which has built so many models illustrating the architecture of the molecule, showing how, in all probability, the links subsist between the atoms of an alcohol or an ether.

One after another various forms of energy once called potential have been brought into line with energy actual, have been reasonably explained as meaning nothing more or less than motion; is it not time that old conceptions of motion should be expanded so as to include the phenomena of gravity as well as all the others once deemed to consist in mere "advantage of position"? Gravity can be imagined as a special molecular motion in its propagation either instantaneous or too swift for existing means of measurement. This supposition may be an unwelcome one, but what is the alternative? Whereas the physicist of to-day holds that the chemical energy of such an element as carbon, the elasticity of a coiled spring or of a confined body of gas, and the quality we call temperature, all denote real activities, nevertheless, the lifting of a weight, into which any of these activities can be readily transformed, is not represented by motion at all, but by an ultimate and unnamed something else. Whether is it better to cherish a conception in its inherited form or to try to broaden it as the facts demand? For the inclusion of gravity among the phases of veritable motion there is cumulative suggestion. When in every other phase of energy there is either detection of motion in what seeems rest, or an assumption of motion the validity of which is proved in the fulfillment of the predictions to which it leads, the hint is clear. It is that gravity, too, will be demonstrated as motion by future means of inquiry which may as far transcend our present resources as these surpass the methods of the men of science who, not so very long ago, could bring forward reasons for believing phlogiston to be a substance and electricity to be a fluid.

The advance of knowledge thus far has been a process of identification. Heat, chemical affinity, electricity, magnetism, and all the other forms of palpable energy are now held to differ from one another only as do the circles, spirals, and straight lines de-

scribed by the wheels and levers of the machine shop. In an ever-extending curve the physicist has arranged a continuous series of real activities, a wide diversity of energies once deemed "potential," static, at perfect rest. Is it reasonable to maintain that this curve of his, almost a full circle, does not form part of a real circle, that the small arc which yawns where gravity can fit with the completing effect of a keystone, represents a discontinuity in the nature of things? Preferable, because more probable, is the idea that the scope of kinetic explanation is universal, that the whole scheme of physical Nature represents in its every part and function an enginery upon whose ceaseless action hinges the drama, ever more involved, of plant and animal and human life.

To men who knew only what had befallen themselves and their dwelling place during a few generations, it was but natural to repeat: "The thing that hath been, it is that which shall be; and that which is done, is that which shall be done; and there is no new thing under the sun."* But we of to-day are in different case. The astronomer, joining camera to telescope, expands the sphere of the known universe a million fold; he discovers system after system in stages of life such as our sun and its attendant orbs have passed through in ages so distant as to refuse conception. The geologist, deciphering the birth register of our planet's oldest rocks, gives them a lifetime scarcely to be distinguished from eternity. The range of time, thus broadened, permits to the smallest arc of change a sweep wherein it becomes a circle of profoundest transformation. The naturalist, his tasks of mere description almost at an end, finds their chief value to lie in their furnishing data for the new question, How did all this diversity of life become what it is? Ever the keynote of reply is action and reaction, unending stimulus and response. Permanence is only a seeming, the truth behind it is universal plasticity and change. In the organic world this passing from appearance to cause has restored soul to body, and made intelligible for the first time both form and substance, by referring them to the forces which mold and inform every material frame of life. In the inorganic world it will be the same; the force which binds sun to planet, pebble to seashore, will yet be understood as part of the unbroken round of all-comprehending motion.

THE pterodactyls, it appears, are not yet all dead. Mr. E. M. Magrath says, in the London Spectator, that a small flying lizard is still to be found on the southwestern coast of India, of which he had some stuffed specimens—given away, however, years ago, to a distinguished naturalist.

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* Ecclesiastes, i, 9.

THE NOCTURNAL MIGRATION OF BIRDS.

By FRANK M. CHAPMAN.

NO branch of ornithology offers more attractions to the student of birds than the fascinating subject of migration. Birds come and go; absent to-day, to-morrow they greet us from every tree and hedgerow. Their departure and arrival are governed by as yet unknown laws; their journeys through the pathless sky are directed by an instinct or reason which enables them to travel thousands of miles to a winter home, and in the spring to return to the nest of the preceding year.

Volumes have been written to explain their mysterious appearances and disappearances.

Theories almost as numerous as the essays themselves have been advanced to account for the phenomena of migration. From the time of Jeremiah (viii, 7) to the present day we might cite a host of authors who have contributed to the literature of the subject. It is not our intention, however, to review the whole question of migration. The combined researches of ornithologists have placed it among the sciences, and its more prominent facts are common knowledge. We desire here to call attention to but one phase of the study, and more especially to outline some recent investigations in connection with the nocturnal migrations of birds.

From the nature of the case, our data concerning these night flights have long been meager and unsatisfactory. Even now our information has but reached a stage which permits us to intelligently direct further effort.

We know that the land birds which migrate by night include species of more or less retiring disposition, whose comparatively limited powers of flight would render them easy victims for birds of prey if they ventured far from the protection of their natural haunts during the day. Thus we find that the bush- or tree-loving thrushes, wrens, warblers, and vireos all choose the night as the most advantageous time in which to make their long semi-annual pilgrimage, while such bold rovers as swallows, swifts, and hawks migrate exclusively by day.

The information we possess concerning the manner in which the first-mentioned class of birds accomplish a journey which leads them from boreal regions to the tropics, has been derived from three sources: First, through the birds which are killed by striking lighthouses or electric-light towers; second, through observations made at night from similar structures; and, third, through the use of the telescope.

It has long been known that lighthouses are most destructive

to night-migrating birds. Probably no one artificial cause produces more disastrous results than these beacons which guide the mariner in safety, but prove fatal obstacles in the path of aërial voyagers.

The number of birds killed by striking lighthouses is incalculable. Over fifteen hundred have been found dead at the foot of the Bartholdi Statue in a single morning; while from Fire Island (Long Island) light we have a record of two hundred and thirty birds of one species—black-poll warblers—which met their fate on the night of September 30, 1883.

Reports from numerous lighthouses show (1) a great variation in avian mortality at different localities; (2) that as a rule no birds are killed during clear nights; and (3) that comparatively few birds strike the lights during the vernal migration. The fact that birds follow certain routes or highways of migration in their journeys to and from the South doubtless explains their absence or presence at a given locality; indeed, it has been definitely ascertained that lights which are situated in known lines of migration—as, for example, the Bartholdi Statue at the mouth of the Hudson River Valley—prove far more destructive than those which are placed far from the regular routes of migrating birds.

Through telescopic observations, to be mentioned later, we have learned that when *en route* birds travel at an altitude of from one to three miles above the earth. It is obvious, then, that when their way is not obscured by low-hanging clouds they pass too far above us to be attracted by terrestrial objects. It has been noted that cloudy and especially rainy nights are most disastrous to migrants, evidently because the formation of moisture at the elevation at which they are flying must not only interfere with their progress, but in veiling the earth below robs them of their landmarks, while the condensation of this moisture into rain presents an effectual check to flight. The birds then descend to a lower altitude, and, should the storm be very severe, they are obliged to seek the nearest shelter, and even may be driven to earth wet, helpless, and dying.

The influence thus shown to be exerted by meteorological conditions is the best explanation of the comparatively small number of birds killed during the spring migration, when the infrequency of violent storms enables them to perform their journey with less danger from exposure to the elements.

The observations of Mr. William Brewster on the migration of birds at the Point Lepreaux (Bay of Fundy) lighthouse have never been exceeded in interest or value by the recorded experiences of any other observer of similar phenomena. Still, even his graphic account fails to produce the sensations which possess

one when for the first time the air at night is actually seen to be filled with the tiny songsters which before were known only as timid haunters of woods and thickets.

On September 26, 1891, it was the writer's good fortune to pass the night with several ornithologists at the Bartholdi Statue in observing the nocturnal flight of birds. The weather was most favorable for our purpose. From the balcony at the base of the statue we saw the first bird enter the rays of light thrown out by the torch one hundred and fifty feet above us at eight o'clock. During the two succeeding hours birds were constantly heard and many were seen. At ten o'clock a light rain began to fall and for three hours it rained intermittently. Almost simultaneously there occurred a marked increase in the number of birds seen about the light, and within a few minutes there were hundreds where before there was one, while the air was filled with the calls and chirps of the passing host.

The birds presented a singular appearance. As they entered the limits of the divergent rays of light they became slightly luminous, but as their rapid wing-beats brought them into the glare of the torch they reflected the full splendor of the light, and resembled enormous fireflies or swarms of huge golden bees.

At eleven o'clock we climbed to the torch and continued our observations from the balcony by which it is encircled. The scene was impressive beyond description; we seemed to have torn aside the veil which shrouds the mysteries of the night, and in the searching light reposed the secrets of Nature. As the tiny feathered wanderers emerged from the surrounding blackness, appeared for a moment in the brilliant halo about us, and continuing their journey were swallowed up in the gloom beyond, one marveled at the power which guided them thousands of miles through the trackless heavens. While by far the larger number hurried onward without pausing to inspect this strange apparition, others hovered before us like humming birds before a flower, then wheeling retreated for a short distance and returned to repeat the performance or pass us as did the first class mentioned, while others still, and the number was comparatively insignificant, struck some part of the torch either slightly or with sufficient force to cause them to fall stunned or dying. It was evidently by the merest accident that they struck at all; and so far as we could judge they were either dazzled by the rays of the light and thus unwittingly flew directly at the glass which protects it, or came in contact with some unilluminated part of the statue. During the two hours we were in the torch thousands of birds passed within sight, but less than twenty were killed.

This fact, in connection with the comparative or entire absence of birds on clear nights, very plainly shows that conclusions based

solely on these casualties may be not only misleading but erroneous. In other words, the number of birds which strike a light is a poor index to the number which have flown by or above it in safety.

Throughout the evening there was a more or less regular fluctuation in the number of birds present; periods of abundance were followed by periods of scarcity, and the birds passed in well-defined flights, or loose companies, probably composed in the main of individuals which had started together.

The birds chirped and called incessantly. Frequently, when few could be seen, hundreds were heard passing in the darkness; the air was filled with the lisping notes of warblers and the mellow whistle of thrushes, and at no time during the night was there perfect silence. At daybreak a few stragglers were still winging their way southward, but before the sun rose the flights had ceased. The only birds identified were several species of warblers and thrushes, one red-eyed vireo, two golden-winged woodpeckers, one catbird, one whip-poor-will, and one bobolink. The most interesting and important results of the night's observations were, the immediate effect of rainfall in forcing birds to migrate at a lower level, the infrequency with which they struck the torch, the immense number which passed beyond its rays, and the constancy with which they called and chirped as they flew.

An almost virgin field awaits the investigator who will systematically observe night-migrating birds with the aid of a telescope. Messrs. Allen and Scott, at Princeton, and the writer, assisted by Mr. John Tatlock, Jr., at Tenafly, New Jersey, and at the Columbia College Observatory, have alone recorded the results of observations of this nature. Their labors, however, were too brief to more than show the possibilities which await more extended effort.

A comparatively low-power glass is focused upon the moon, the birds appearing silhouheted upon its glowing surface as they cross the line of vision. Some idea of the multitude of feathered forms which people the upper regions of the air at night may be formed when it is stated that during three hours' observation at Tenafly no less than two hundred and sixty-four birds were seen crossing the restricted field included in the angle subtended by the full moon. Under proper focal conditions, birds were so plainly visible that in many instances marked character of flight or form rendered it possible to recognize the species. Thus ducks, snipe, and sora rail were distinguished with certainty.

The effect on the observer of this seeing of things unseen is not a little curious, and may be likened to the startling disclosures which a high-power microscope presents in a drop of water.

From calculations based on an assumption that birds were not

visible beyond a distance of five miles, we determined the greatest altitude at which birds migrate to be three miles above the earth's surface. Many, however, fly at a lower level; indeed, it is not improbable that certain species may, with more or less regularity, travel at a given altitude, and that this altitude may vary among birds of different families. With little doubt thrushes and warblers travel at a much lower level than do ducks and geese, a circumstance which may account for the great abundance of the first two named and the comparative absence of the last in the vicinity of lighthouses.

Such, in brief, are the sources and methods to which we owe our knowledge of the nocturnal flight of birds. It will be evident to the most casual reader how incomplete are our data. The time is still far distant when we can hope to conclusively account for the many perplexing phenomena of migration, but we may be pardoned if, in conclusion, we briefly review the bearing of our present information.

We need not discuss here the origin of migration or the causes which now induce birds to undertake a long and perilous journey twice each year. But the power and influences which guide a bird, in the darkness of the night, through space, and render a definite migration possible, are subjects kindred to our inquiry and worthy our attention.

Until we possess some exact knowledge of the distance to which birds can see we can not estimate the aid their vision is to them while migrating. We know, however, that the avian eye is far more powerful than ours, and it is fair to assume that to some extent their journeys are directed by a sight which enables them to follow mountain chains, river valleys, and coast lines, and to distinguish distant headlands or islands. At an altitude of two miles an object would be visible ninety miles and the horizon be separated by twice this distance. At no time, therefore, in their journey from North to South America are birds necessarily out of sight of land. But that they do venture beyond a point where land is visible is shown by the regular appearance of migrants in the Bermudas, six hundred miles from our coast, while Jamaica, four hundred miles north of the nearest point of South America, is a point of departure for many south-bound migrants. Here, with neither islet, shoal, nor reef to mark the way, it is evident that sight alone would prove an insufficient guide, and they must rely on some other sense. Primarily, this is the inherited habit which prompts birds to fly southward in the fall and to return in the spring. But, given the impulse of direction, there is little doubt that one of the best guides to night-flying birds is the sense of hearing. Birds' ears are exceedingly acute. They readily detect sounds which to us are inaudible. Almost invariably

they will respond to an imitation of their notes. We have seen that when under way they constantly chirp and call, and when we take into consideration their aural power and their abundance in highways of migration, it is probable that at no time during the night is a bird out of hearing of its fellow-travelers. The line of flight once established, therefore, presumably by the older and more experienced birds, it becomes a comparatively easy matter for the novice to join the throng.

MODERN VIEWS AND PROBLEMS OF PHYSICS.

By DANIEL W. HERING, C. E.,
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A GOOD idea of the generally accepted views upon a science in all its branches may be obtained by inspecting standard text-books on the subject, for such works are not likely to meet with the approval of scholars, and especially of professors, if they present views that are antiquated in form or palpably erroneous in statement.

In thus approaching a modern text-book of physics, to a beginner, or one with no preconceived ideas on the subject, there would perhaps appear nothing surprising, but to an older student, say the college alumnus of fifteen years' standing who has not kept abreast of the science, the change would be striking. He would probably be impressed as much by the absence of things he had thought inseparable from the subject as by the presence of things of which he heard little or nothing in his college course. An illustration of this may be seen in a very recent book of the kind named.* In its general tone it is similar to that adopted about ten years earlier in the masterly presentation of the Principles of Physics, by Prof. Daniell, but it is less conservative than that work. A glance at the headings gives the keynote of the whole treatment. After a brief discussion of kinematics and dynamics, *mass physics* is further divided into work and energy, attraction and potential, properties of matter, energy of mass vibration, sound. Then physics of the ether has energy of ether vibration, radiant energy, energy of ether stress, electrostatics, energy of ether vortices, magnetism, energy of ether flow, electro-kinetics, electro-magnetic character of radiation.

There is not an allusion to the old familiar "simple mechanical powers"; there is no mention of light or optics as a branch of physics; sound, heat, electricity, and magnetism are only ap-

* Barker's Advanced Physics.

pended as subtitles to more general terms expressing forms of energy, and appended in a way that would permit them to be dropped altogether without detriment to the treatment of their phenomena. Not that the phenomena are different from what they were in former times, but they have become much more effectually correlated in a general scheme of energy. Such a mode of presenting the subject might be ascribed to a mere desire to break away from conventional lines, but it is in strict accord with the work and conclusions of physicists generally in the last quarter of a century and especially within the last decade. Physicists accept fully the mechanical theory of heat. They regard the heat of a body as the aggregate kinetic energy of the molecules. They accept in general the kinetic theory of gases, but are not uniform in their views as to the extension of this theory to liquids and solids. In the mechanical theory of heat, however, the idea that all the molecules of all bodies are in motion is fundamental. Nowadays, instead of ascribing phenomena to the action of mysterious "forces," with perhaps a force of one kind for gravity, of another kind for thermal or electric or magnetic effects, and treating force as a real agent bringing about changes, it is the custom to recognize in any body or system of bodies a certain quantum of energy of which the form or distribution is altered by a change in the form or configuration of the body or system of bodies. Energy is the thing studied and force is merely the rate at which the energy of a body is altered in comparison with the change in the position or shape of the body. The term force is still in use for convenience and brevity, but the objectivity of force has disappeared. Force is not a real thing at all, but energy, like matter, has an objective existence. Also, when force was regarded as an agent, it was discussed as acting at a distance without regard to a medium for transmitting action from one body to another, or, as we now say, for conveying energy. But if bodies possess and exchange energy, and energy is only perceived by us in connection with matter, we find it proper not only to recognize a medium throughout space, but to discuss the forms in which energy exists in that medium, which is spoken of as ether. The idea of such a medium is not modern. After pointing out that the hypothesis of an ether was a device often resorted to for the purpose of mystification as much as explanation, Maxwell says: "Ethers were invented for the planets to swim in, to constitute electric atmospheres and magnetic effluvia, to convey sensations from one part of our bodies to another, and so on, until all space had been filled three or four times over with ethers. It is only when we remember the extensive and mischievous influence on science which hypotheses about ethers used formerly to exercise that we can appreciate the horror of ethers which sober-

minded men had during the eighteenth century. . . . The only ether which has survived is that which was invented by Huygens to explain the propagation of light." *

Those ethers were working hypotheses which might be expected to give way wholly or in part to better ones constructed for working purposes under fuller knowledge. So, too, at first, was the luminiferous ether, which, as a hypothesis, had to be endowed arbitrarily with properties suited to the phenomena it was to account for, but *the ether* of modern science is accepted as beyond question. For example, Lord Kelvin says: ". . . This thing we call the luminiferous ether. That is the only substance we are confident of in dynamics. One thing we are sure of, and that is the reality and substantiality of the luminiferous ether." † It is not necessary here to go into the evidences of its reality, but our belief in it rests upon exactly the same kind of evidence and just as strong evidence as does our belief in the existence of any kind of matter. For we only infer the existence of any form of matter from its phenomena, and the phenomena of light, heat, magnetism, and electricity to the extent of a very large group are not only explainable but are best explainable by the assumption of the ether. The defect as yet in such an assumption lies in the fact that the ether is a substance of an unfamiliar kind. It is this want of familiarity that physicists to-day are doing their utmost to overcome, and the more it is examined the more are they impressed by the multiplicity of purposes which this one medium is competent to serve and which it seems to be serving. The time for doubting its existence is past—it is now only a question as to its nature and properties; and it is accepted as a fact, not merely a hypothesis, that the same medium is concerned, if not a principal factor, in the phenomena of light, heat, magnetism, electricity, and gravitation. Radiant heat and light are wave motion in the ether, and are similar forms of energy, the only difference being in the period of vibration. Their manifestation as energy only occurs when the vibrations affect matter, and this, the most difficult part of the subject, involves the relation between ether and ordinary forms of matter. We say "ordinary forms" of matter, because ether may or may not be considered a form of matter.

One of the great, the primary questions of science is, What is ether? The question, What is light? has found its answer, so too has the query as to heat and as to sound; as to electricity, not so assuredly or so definitely, but both it and magnetism are to find their explanation through this same medium in some way or

* Article on Ether in the Encyclopædia Britannica.

† Popular Lectures and Addresses, by Sir William Thomson, vol. i, p. 317.

other. There is no longer any doubt about that, and Maxwell's theory, which rests upon this idea fundamentally, has a strong hold upon modern science and a hold that is growing stronger as research advances.

We know the ether as a vehicle of energy in several forms, and when various agencies are collected into a group of forms of energy there is still the question, "What is energy?" These general problems now engaging the attention of the physicist—viz., the ultimate nature of matter, by which the properties of matter may be accounted for; the nature of the ether and its properties; the mutual relations subsisting between matter and ether, if they are different things; the nature of energy, and whence it arises, and whether it is primarily potential or kinetic—these, in part at least, are not new problems, but they are now approached from new directions, along new ways, and by the aid of new light. Under each of these heads appear numerous special questions, and along all these lines investigators are working earnestly.

The attempt to explain the nature of ether or of matter at once raises the question whether ether is matter. Now, of course, a great deal depends upon the definition of terms, and it is perhaps best to confine our attention at first to the structure of matter rather than its nature. The properties and behavior of matter as it is ordinarily recognized are largely known, the actions and functions of the ether are largely known, and it is only a question of the propriety or possibility of including both in one general view. Clerk Maxwell * regards as a proper test of a material substance its ability to contain and transmit energy. He then points out that energy can not exist except in connection with matter; that in the space between the sun and the earth, the luminous and thermal radiations which have left the sun and which have not reached the earth possess energy in definitely measurable amount, and therefore this energy must belong to *matter* in the interplanetary spaces. On the other hand, Prof. Dolbear stands as an exponent of the views of others who decline so to class the ether when he says: "If, then, the ether fills all space, is not atomic in structure, presents no friction to bodies moving through it, and is not subject to the law of gravitation, it does not seem proper to call it matter." † But Prof. Dolbear has previously announced as his criterion of matter, the possession of the property of gravitative attraction. On such grounds we may concede each view to be correct, but we are brought at once to the old question, "What is matter?" It is the view of some that, with the present limitations of intellect, it is beyond

* Matter and Motion.

† Matter, Ether, and Motion.

our powers ever to conceive of the ultimate nature of matter. Of the structure of matter this is not the case. Various hypotheses have been offered regarding the structure of matter—all, save one, have been charged with some fatal objection and have broken down. This one, the suggestion of that powerful mind, Lord Kelvin's, is known as the vortex-ring theory. We can not give it here in any detail, but the gist of it is that the ether is universal and for the most part formless, but that some parts are differentiated from the remainder by being in motion in the shape of vortex rings. These parts in such rotational motion are matter in the ordinary forms. A remarkable thing about it, and one which exhibits the very spirit of modern physics, is that those properties of ordinary matter which emphasize its stability of form and position, especially inertia, elasticity, and rigidity, *can be a result of motion.* Yet Lord Kelvin has shown that with ordinary matter a limp system of bodies could be made a rigid system by merely putting them into gyroscopic rotation, and also that elasticity itself might properly be regarded as a mode of motion. The vortex-ring theory is as yet only a speculation, but when its adaptability to occult as well as to plainer properties of matter are considered, we need not wonder that it has been thought so beautiful that "it deserves to be true." At any rate it stands in such an attitude toward modern views concerning the structure of matter that "it is either that theory or nothing. There is no other one that has any degree of probability at all" (Dolbear). We can see how such a theory might reconcile conflicting views such as those above given concerning matter and ether separately.

Without waiting for a decisive answer as to the nature of ether or the structure of matter, attention is being concentrated on the relations of one to the other, the extent to which and the manner in which any change in either substance affects the other; and this examination may throw light upon the greater question regarding the nature of the substances. Do material bodies moving in the ether of space—for example, the earth and its atmosphere—move through the ether, or carry with them the ether that is distributed throughout the matter that is moving? Experiments of extraordinary precision by Prof. Michelson have led him to conclude that most probably the earth carries with it all the ether in its immediate neighborhood; that certainly the relative motion of the earth and the ether in it is exceedingly small. If he can repeat his experiments and get a different result on the top of a mountain, that conclusion may be considered established. Those conclusions were drawn from experiments in which the earth's velocity in its orbit is involved. Prof. Lodge has experimented for effects due to slower motion of bodies upon

the earth. He says: "I do not believe the ether moves. It does not move at a five-hundredth part of the speed of the steel disks" (used in the experiment). "I hope to go further, but my conclusion so far is that such things as circular saws, fly wheels, railway trains, and all ordinary masses of matter do not appreciably carry the ether with them. Their motion does not seem to disturb it in the least."

Among the more special questions undergoing investigation at present by the application of physical principles is the determination of the relative motion of the heavenly bodies by spectroscopic methods. It is done by applying to light-waves what is known in acoustics as Doppler's principle. The position of any line of the spectrum depends upon the wave length, or, what comes to the same thing in this case, the period of vibration for the particular set of waves making the light at that line in the spectrum. By increasing the number of waves per second that fall upon the prism (or grating) of the spectrometer, the period is correspondingly decreased, and conversely. Therefore, while the rate of vibration remains constant, if the grating is moving toward the source of vibration, the number of waves per second falling upon the grating will be greater, and their period smaller, than if the source and the grating are stationary relatively to each other. If they are separating, the period of vibration is increased. In the former case the line of the spectrum will be more refracted, in the latter less refracted, than in a normal case. When a spectrum line of any of the heavenly bodies has been identified with that of any substance known to us, the spectrometer gives the means of determining the motion of such heavenly bodies as compared with the motion of the earth, by observing the displacement of the spectrum line. That is, it is possible to determine whether the earth is approaching the star or nebula or receding from it, and at what rate. This method was proposed and attempts were made to apply it very early in the history of the spectroscope, but the means of observation were not then sufficiently fine, and only negative results were obtained. Within the last few years, however, Prof. Huggins, Prof. Vogel, and others in Europe have made many successful measurements of this character, and Prof. Keeler, of the Alleghany Observatory, has greatly extended them. These relative motions are usually reduced to the sun, the results indicating the relative motion of the sun and the heavenly body observed. As instances, Prof. Keeler finds that the great nebula in Orion is receding from the sun at the rate of eleven miles per second; and by observations between April and August, 1890, the sun was at that time approaching the bright star Arcturus at the rate of four miles and three tenths per second. These serve as a fine illustration of modern methods

of research and the degree of precision attainable. The trustworthiness of the method is shown by the close agreement between its results when applied to the other planets, and the velocities computed from the known astronomical motions of the same bodies.

It is usually thought necessary to caution students of electricity against regarding either of the hypotheses, known respectively as the two-fluid and the one-fluid hypothesis, in the light of an assured thing, and the lecturer commonly hastens to declare that no one knows what electricity is. The declaration is as just as the caution; but it is not in human nature to allow such a declaration long to stand unchallenged. The very fact that it is possibly correct is a stimulus to investigation. Recent research has not conclusively shown what electricity is, but it has considerably shaken the foundations of the above assertion regarding it, and some singular views have been developed that indicate light ahead. We are learning that although the terms "electrification" and "electric" may continue in service to express a condition of matter or to characterize particular phenomena, yet the very name "electricity" may probably become useless and vanish from the vocabulary of physics, for the reason that, instead of electricity being any object, it is probably only a mode in which the ether makes itself manifest. One of the latest views, strongly advocated, is that ether may be analyzed into two constituents, equal and opposite, each endowed with inertia and each connected with the other by elastic ties which are weakened or dissolved by the presence of gross matter. The two constituents are called positive and negative electricity respectively, and of these two electricities the ether is composed. Electric currents which are obtained in such diversity and magnitude for commercial purposes are in almost every case the result of electro-magnetic induction, and are not due to the action of a battery. Yet there is no difference electrically between the currents obtained in the two ways. Maxwell's theory, which treats electro-magnetic action as a variation of ether stress in the medium in which the conductor is situated, may be applied to the conductors of battery currents also, and the medium surrounding the conductor in all cases is the home of the energy transmitted (as we are in the habit of saying) along the wire. But the energy is not transmitted by the wire; on the contrary, the wire, in just so far as it is a good conductor, fails to transmit the energy (the strain) which the action of the generator has sent out into the surrounding medium, and which breaks down or gives way in the conductor. "The energy of a dynamo does not, therefore, travel to a distant motor through the wires, but through the air. The energy of an Atlantic cable does not travel through the wire strands, but through the insulating

sheath. This is a singular and apparently paradoxical view, but it is well founded" (Lodge). And even as to the power of a wire to conduct whatever it does conduct, a special feature has risen into considerable prominence. The most important principle for many years in the study of electricity has been Ohm's law, which states that the resistance of a conductor may be measured by the ratio of the electro-motive force to the current strength. This law when first enunciated was scrutinized closely, demurred against by some experimenters, and shown mathematically to be impossible if carried to extreme applications; it was re-established and experimentally and mathematically proved correct, chiefly by Kirchhoff's work; and is now known to be inaccurate as an expression of the effect transmitted (or resisted) by a conductor under rapid alternations of current, so that to express the energy transmitted under such circumstances another factor has to be taken into account besides what is usually regarded the resistance. This additional quality is called the *impedance*, and the total resistance of a circuit carrying periodic currents is made up of the ohmic resistance and the impedance. The latter has no value when the current is steady, but has reference only to the time while the current is rising from zero to its maximum strength. The principle of impedance was known a good while ago, but it has only demanded the attention of electricians since the alternating currents have begun to be employed on any considerable scale. Ohm's law is just as true as it ever was, but the limitations of its applicability are now better recognized than formerly.

A rapid succession of electric discharges sets up strains and relaxations in a non-conducting medium, which result in the propagation of waves of electro-magnetic induction through it. With oscillations of great frequency, the waves become short enough to be observed and measured readily, and the recent experiments of Hertz show so many features of similarity in the laws and phenomena of reflection, refraction, and speed of transmission of these waves and of light as to sustain Maxwell's theory of the electro-magnetic character of light.

Advances in science are often the outcome of efforts to apply its principles in the arts. A great problem of physics which engineers have to solve is to find economical means of utilizing the energy that Nature is ready to furnish in place of the present wasteful ones. The inefficiency of the best steam engine is a standing reproach to an inventive age. The reproach is to be removed not by the improvement of the steam engine—for its limitations are such that, in the nature of things, it can not be highly efficient—but by the substitution of a better type of machine. Ether vibrations bring us energy in the form of heat, light, or electricity, ac-

cording to their periods and amplitudes; but these, instead of being available in any particular form, are always more or less complex. If we could produce waves of just the rate and amplitude we desire, without any others in combination, a great step would be gained. Then we could produce light without wasting at the same time a great amount of energy in producing heat which we do not want. This is one of the subordinate problems awaiting solution. If to the production of such waves as are wanted we could add a means of recording and fixing them in their true relative proportion, we would have the solution of another great and fascinating subordinate problem—the exact reproduction of natural scenes in color. A long step has been taken toward accomplishing the first of these achievements in the remarkable experiments by Mr. Tesla with alternating electrical currents of high frequency and high potential. Among the startling facts brought out in these experiments is that although a current of electricity, either direct or alternating, from ordinary dynamos under fifteen hundred or two thousand volts electro-motive force will kill, yet under alternations of a million to a million and a half per second a voltage of fifty thousand produces no shock or injury. Electric lamps light with but a single wire leading to them. Vacuum tubes become luminous in a properly prepared room with *no wires*, and it is not extravagant, in view of what has already appeared, to predict a future when unlimited power will be available at every man's hand. That will be when, as Mr. Tesla says, we are able to "hook our machinery to the machinery of Nature." In the conclusion of his lecture before the Institution of Electrical Engineers, London, after describing a plan by which he thinks it would be practicable to telephone across the Atlantic, he adds: "But such cables will not be constructed, for, ere long, intelligence—transmitted without wires—will throb through the earth like a pulse through a living organism. The wonder is that, with the present state of knowledge and the experience gained, no attempt is being made to disturb the electrostatic or magnetic condition of the earth, and transmit, if nothing else, intelligence." It is probable that this wonder will give place to a still greater at no distant period, by reason of successful attempts of just the kind here mentioned. The problem is already in course of solution, the distinguished electrician, Mr. Preece, having recently succeeded in sending telephonic messages over a circuit which was wholly disconnected from that in which the generator was placed, and at a distance of three miles from it.

Unquestionably one of the most powerful aids to investigation of late has been photography. Both as a science and as an art it has grown in precision, speed, and availability, until now it has become a weapon of attack as well as a means of record. While

owing more itself to chemistry than to physics, in the latter especially has it been of assistance to the spectroscope, so that the experimenter is not dependent upon the observations of the moment to make his comparisons. The most considerable work of this kind has been done by Prof. Rowland within the last half-dozen years, in making remarkably large and detailed photographs of the solar spectrum, the spectrum itself, in its perfection and beauty, being due to the matchless gratings constructed under Rowland's directions. Photography has proved to be an unassailable recorder for all the natural sciences, and is likely to become more and more firmly established as such. Disputes over priority in discovery will become less frequent since investigations made in solitude will appeal to their photographic record as a safe witness, impartial and indisputable.

Another subordinate problem is to determine the intensity of sound in absolute measure. Acoustics has been studied with reference to the energy involved less than other branches of physics, although we easily recognize some transformations of such energy into mechanical in the phonograph and electrical in the telephone. But most determinations of the intensity of sound have been relative, by comparison of different sounds, or else the same sound at different distances or in different media. They have not been expressed in absolute units. Absolute values of radiant energy, in the form of heat and light, have been determined, but the methods have not been sufficiently simplified to make them readily applicable in experimenting. Temperatures are still given in arbitrary degrees, and intensity of illumination has no acceptable basis expressible in terms of the fundamental quantities mass, time, and distance, although several methods have been suggested in which the direct, subjective estimate of it by the eye plays no part.

This brings us to a consideration of the great service rendered to scientific investigation by an absolute system of units and measurements. Such systems were instituted by Gauss and Weber between the years 1834 and 1850, and their introduction was especially fruitful in the study of electricity. The mechanic was enabled by that means for the first time to compare the electric forces produced with the mechanical ones employed, and gained thereby for the first time a just estimate of the former. The adoption throughout the scientific world of the centimetre-gramme-second absolute system for all branches of science is by no means the least valuable outcome of the development which electrical science has undergone since 1850, for in the possibility of tracing back all natural phenomena to the three mechanical units of space, mass, and time, science received new evidence for the inherent unity and the mechanical character of all forces of

Nature. Energy as considered in physics, apart from chemistry, has been classified in various forms, viz., energy of motion (translation or rotation), strain, vibration, heat, radiation, electrification, electricity in motion, magnetization, and gravitative separation. Those forms which are represented directly by bodies (whether extended masses or molecules) in motion or deformation, and which do not appeal to our special senses for recognition, constitute mechanical energy. The first two named above are plainly such, and all the others except the last have been shown to be such indirectly; it is generally believed that the last will be found to be reducible to the same form, so that probably all are essentially mechanical, and physicists are hoping to reduce them all to the mechanical as the ultimate form of energy. The importance to the physicist, therefore, of an acquaintance with the principles of mechanics can not be overestimated: without such an acquaintance his efforts to unravel the mysteries of physical science or to gain possession of its secrets will be futile.

FORM AND LIFE.

By M. GEORGES POUCHET.

IN the first glance over Nature, everything living, every plant or animal, and every part of what lives, seems to have a definite shape; and we are naturally led to regard form in organized beings as an essential attribute of life. On the other hand, gases, which spread out into infinity; liquids, molding themselves on the walls of the vessels that stop their flow; rocks, cut into a thousand shapes without ceasing to be the same rock—show us an inorganic world almost wholly freed from the fatality of form. Crystals, indeed, seem to form an exception to this. They also have limited shapes, with contours even much better defined than those of life; but when we bray them in a mortar, they are still always the same body, and the same chemical species, even though they are no longer crystals. A living being, sugar cane or beet root, rasped or reduced to pulp, has no longer anything of itself. It has ceased to be, and no power can, from the pulp, build the organism back into its former shape. But we can reconstruct the crystal, and draw it anew from its dust.

The living being, considered in itself, independently of the being from which it is derived and those which will be derived from it, is, in its way, with some exceptions, a sort of atom, an indivisible whole. Hence that very just denomination of *individual*, to designate the being endowed with life.

What we call species in speaking of plants and animals is

really only the grouping made in our mind of all the living individuals exhibiting the same form, and which we believe to be all united under a common parentage.

Yet form can not serve of itself to characterize life, for there exist other bodies than crystals in the inorganic world which are individuals. The planets and the rings of Saturn will at once occur as examples. We might also range in the same category comets and whirls of smoke, which are likewise individuals, and cease to be by the mere fact of their division or dissociation.

Form is therefore not sufficient to characterize the living individual. Let us see if the general features and external aspect of organized beings will not offer us marks to distinguish them from mineral bodies. The plane faces, the sharp edges, and the definite angles of crystals, and the spherical contours of the heavenly bodies, have been contrasted with the undulating surfaces, the less geometrical and more softly defined profiles of plants and animals. This trait is certainly not destitute of value, and the untrained mind is rarely deceived by it. Sometimes the lapidary, in cutting agate, uncovers delicate arborescent shapes in the transparency of the gem. The illusion is vivid, and one might fancy he had a petrified moss under his eyes. A lens will assure him that there is no vegetable fossil here, and will reveal an assemblage of crystalline needles that have nothing in common with the delicate articulations and waving lines of a genuine moss.

Its particular stamp is so clearly impressed on each living being and on each of its parts, and it is so recognizable that it guides the naturalist with certainty, even when he affirms, from the smallest remnant or weakest impression, the existence on the surface of the globe, in prodigiously distant times, of beings that lived then, and with which he is unacquainted. Some of the organisms have left only traces, and he affirms that life passed there, without knowing whether it was vegetable or animal.

The ancients, although they had not our experience in interpreting the true nature of fossils, never failed to recognize the factory mark which Nature impresses on its works. Science then gave no means of discerning in ammonites the shell of an animal allied to the squids and cuttlefish; but the finders had at least the feeling that these things had lived, and, by analogy, they saw in them the bones of animals preserved in the earth.

Form is not an essential attribute of life. There exist living beings destitute of living form, as there exist chemical substances that do not crystallize. The microscope reveals in stagnant water gelatinous masses that change their form and move incessantly. We see a part of the mass stretch out like a foot advancing. Then the whole being seems to pass into this prolongation, which is proportionately swelled out. Another expansion occurs at an-

other point, and the viscous drop, changing shape continually, seems to flow along slowly. If it meets any vegetable matter, it envelops it, and the stuff suffers a real digestion. The residue is cast out, as it was absorbed, by any point of the surface. We call these beings *amœbas.* They are capable of multiplication by division, and every part of them is susceptible of being indifferently surface or inside, the drawing part or the part drawn, mobile all at once. For the amœba can choose its direction and find more light or more darkness according to what we may call its aspirations, since it acts, definitively, as a living being.

If we open a tan vat in the spring, we shall discover here and there irregular golden-yellow filaments, soft and slimy. We observe them changing their place and flowing like the amœbas. They appear to be seeking one another in the mass of tan, for in the summer, after a shower, they may be seen to join, then rise in the shape of a kind of yellow cake, large and thick as the two hands; the botanists call them *myxomyceta,* or the slimy fungus. Detach a part of this mass, put it on a potsherd, and it will, like the amœba, extend branchy expansions, pass itself upon them, stretch out and return upon itself in changing lumps, to be succeeded soon by new stretchings.

We see in these, beings without form, without organs, composed solely of an opaque substance, and highly colored in the myxomycetes, but transparent in the amœba, a little denser than water, with which it does not mix, a substance that moves and feels—that is, that shares with us the higher attributes of life. The discovery of the amœbas was at first merely a curiosity till Dujardin and Hugo Mohl, almost at the same time, called attention to a substance entering into the composition of infusoria and the cells of plants that had all the characteristics of the substance of the amœbas. Dujardin called it *sarcode;* Hugo Mohl, *protoplasma,* and that name prevailed. The term, imposed as the name of one of the constituent parts of the vegetable cell, has had the singular fortune to become almost synonymous with matter living or that has lived.

This amorphous substance is the basis of the organism. In plants, it is what in some way builds up every cell, as the worm and the mollusk produce the shell and the tube that protect them, or as the caterpillar envelops itself with the cocoon which it draws out from its glands. So the protoplasm molds around itself the walls of the cell in which it is inclosed. But it is always the prime living part, and when it disappears the cellular wall becomes only an inert body. In animals, likewise, the egg, or at least its essential part, the *vitellus,* shows in its almost universal spherical form the protoplasm shaped at first only by the laws of attraction and resistance common to all matter. But when the egg takes life, the

first signs it gives of its activity are movements comparable with those of the amœba. Thus, without effort, we find on different sides life freed from form. We comprehend that it is not essentially and fatally bound to form. A body may be living and still have no definite figure. Here the problem is suggested, whether a liquid, a bodily humor, can be living. Is the blood living, like the substance of the nerves or the flesh of the muscles? It is a deep question and has not yet been answered. At any rate, science has been led for a long time to look for the characteristic of life somewhere else than in form.

The Aristotelians saw a movement in what we call life; and they gave that name to every change of state of natural bodies as well as to their translation proper in space. Aristotle's treatise on the Soul characterizes life by the three facts of its nourishing itself, developing, and perishing. Growth and decline are changes, and consequently movements; and, as we always see them closely connected with the feeding of the plant as well as of the animal, we find the act of feeding definitively at the basis of the movement which is life. Moreover, do we not see during growth the parts of which the creatures are composed changing places relatively to one another? Have we not here a clear, absolute distinction from the increase of mineral bodies?

There are, however, some parts in animals which grow by a simple constant accretion of superadded new particles; such as the shells of mollusks, even when they are covered by the flesh, like cuttlefish bone. But these formations, although derived from the organism, are not themselves living. They bear, if we may say so, the stamp and seal of life so far that we can recognize them as a product of it, but no further; and if they grow, it is as crystals do.

Thomas Aquinas, following Aristotle, gave life the most exact definition that could be made with the knowledge of his time. It is almost as satisfactory for us, for we, too, define life in the same terms. It is a movement, but still not one of the apparent though intimate movements to which the Christian encyclopedist alludes. It is a molecular movement that escapes our eyes, in the interior of the being, and is revealed to our senses only by its results.

The movement that constitutes life is an intimate, profound, invisible, incessant movement, at once of combination and of decomposition. Living matter is incessantly born and incessantly dying, being formed and suffering destruction all at the same time.

All liquid or gaseous bodies coming in contact with a living substance and soluble by it, penetrate it, mingle with it, and then, carried on in the whirl, cease for the most part to be themselves, are transformed, enter into new combinations that did not exist

outside of the being, but which are in their turn destroyed and pass into other conditions unsuitable to life, and in which they are cast out to re-enter the inorganic world, which is enriched through them with ammonia, carbonic acid, and oxygen. We are not acquainted with the nature of this movement; we know only that it exists by comparing what goes in and what goes out, and these with the intermediate term, the living substance itself. We know that it is propagated at the same time in all the tissues and all the organs of the being, offering in each a special modality while retaining always the same fundamental character.

This movement is fundamental to the tissues of the living being, from the most simple of them, like the substance of the bone, to the most complex, like that of the muscles or the brain. It is always in the living being, whether it is growing, thriving, or declining toward death, or is attainted with different passional, morbid conditions that might affect it. It is always present in the infinite variety of physiological acts of which our life is made up and which all inevitably lead to an impending molecular modification: the sensation of the retina disturbed by a light-ray, the contraction of a muscle, and even thought. In connection with the last, the effort has been made to reach by tortuous ways the nature of the chemical reactions that necessarily accompany all brain work. Whether this is reached or not, it is impossible to conceive the operation of the nervous elements otherwise than as a phenomenon of nutrition—that is, as a modification brought about in the molecular movement.

But we are still unable to penetrate and discover the true nature of that inner molecular movement which makes of animated bodies a world apart from the great cosmos. What are the origin and nature of that new energy communicated to inert matter, giving it properties or rather faculties which it had not before, and which are additional to all those with which the chemist and physicist are acquainted? Let us say, further, that they are added to these without contradicting them, as was believed for a long time when a kind of antagonism was supposed between life and the physico-chemical forces. Life is in no way a triumph over these forces, and they always keep their predominance.

Vital movement is, after all, only an episodical modality of the universal faculty which simple and compound chemical bodies have of reacting upon one another. It requires for its manifestation, like every other reaction, definite conditions, confined within narrow limits, of pressure, temperature, and light.

But the thing we are absolutely ignorant of is the real nature of those inner reactions of which we can not in many cases give the rigorous formula and still less define the thermic equivalent; the generic quality, as it were, of those movements, at once special

and infinitely varied, which are going on incessantly in the parts of living bodies. We know that the vital movement in each individual is to come to an end at a given moment—that is death. We have a thousand means of provoking a stoppage of it. We can only propagate it in a certain way when we furnish it, by means of food or generation, with the material substratum necessary for its production and development. We can in like manner divert it and cause it to produce monsters; but we have no power to make it appear where it does not exist.

Vital movement is continuous. It was formerly thought possible to suspend it; that seeds and living beings could die for the moment, and the former keep intact their faculty of germinating, and the latter return to a new existence when placed in favorable conditions. Reviving animals have excited much attention, but little thought has till the present been directed to the supposed suspension of life. In reality, these beings continue to live, but extremely little. The vital movement is not suspended, but is considerably diminished rather than retarded, like the vibration of a sounding cord which loses in intensity till it is no longer heard, while the finger can still feel it tremble. About forty years ago some speculators upon public credulity publicly distributed through all Europe, selling it very dear, a wheat which they said had been taken from a mummy in Egypt, and which when planted gave a prolific return. This was a simple cheat. Yet seeds are known which have retained the germinating faculty a very long time; they really continue to live, carrying within themselves the inner movement which becomes slower every day and ends with extinction. The seed will inevitably die; whether it be after a few years or in a century or two makes little difference—it will die.

Vital movement is then continuous, but with incessant renewals, and it also has a very special character. It is propagated indefinitely, while it continually casts off a part of the materials which it had previously animated. That yellowed wheat which the reaper is going to cut, the stubble of which is destined to cover some cottage, the seed of which seems wholly devoted to the support of the life of men, which has to our view not lived a whole year—that wheat is eternal; it has lived through all the past, and may live through all the future. It has dried, but that is only in appearance. Life has not withdrawn from it. Planted next year, it will project a new head, and so on for thousands of years.

We are accustomed to regard as a living being having a kind of beginning and end the head which issues from the seed in the spring, and which autumn will mature. The conception is wholly arbitrary. We really know of no beginning or end to this head. It is not even an individual in the philosophical sense of

the word; for it is connected by continuity with all the heads of wheat that preceded it and with all those that will follow it. The important part is the seed, or the germ which it includes, continuing itself by a stem and a flower into another seed like it. The root, the straw, the glumes are accessories—all to be abandoned every year by the seed incessantly reviving of itself, which veritably incarnates the species *wheat.*

The molecular movement being at the very basis of life, to what extent does it regulate its manifestations? Does it make its influence felt only to maintain the external form or to exert a certain amount of command upon it? It does command it in effect, and all the external characteristics of the species and the individual appear to us definitely as subordinated to the conditions of their inner chemistry. Chevreul was the first who formulated the principle of the absolute dependence of life on the physico-chemical laws of inert matter. The demonstration of it is furnished in the manure and fertilizers by means of which we succeed in prodigiously modifying the external appearance of the plant, to the point of rendering it almost unrecognizable. This sprout, in a dry, arid soil, is stunted, coriaceous, and hairy; that other one, from the same kind of seed, growing in the shade, on a soil constantly moist, is large, plump with water, soft and smooth. Without more knowledge, we should see in them two distinct species, if all the intermediate terms did not meet here and there on grounds half dry or half shaded, to show that we are simply dealing with two individuals of the same species, the molecular constitution of which is not absolutely identical because of the different conditions in which each one has lived.

It was long thought that the plant could choose by its roots the substances in the earth useful in its support and growth. This is not correct. The root, in contact with the extremely complex bodies which are continually formed and unformed in the soil around it, takes all those which the spongy terminal tissue of each radicle can dissolve. The plant is in this case only a reagent like any other; it is passive, and suffers itself to be penetrated by every substance, useful or injurious, in the quantity in which that substance is susceptible of mingling and combining with its superficial tissues. By virtue of the molecular constitution of the walls of the root, and especially of the extreme cells of their fibers, plants absorb particular mineral principles, and these principles in their turn, drawn into the vital molecular movement, favor it, impede it, or modify it in some way, and at last provoke a perceptible change in the aspect of the plant. This direct, immediate influence of molecular constitution on the forms of living beings appears to be more sharply marked in plants, but that is perhaps

because animals have not been so carefully studied with reference to it. Some practices well known to horticulturists demonstrate with a singular evidence this subordination of extreme characters to the chemical composition of living matter—as in some of the methods by which new varieties and colors are obtained.

With the aid of analysis and the balance, Prof. Armand Gautier exhibits to us these new appearances of plants in relation to the formation of new chemical compounds in them. This has been done under such conditions that it can be said of every animal or vegetable hybrid that it does not represent simply the mingling or the combination of the two forms from which it is derived, but is still more the expression of new molecular combinations giving rise to intermediate chemical combinations. We have a right now to affirm that the blood of the mule, in its intimate composition, differs as much from the blood of the horse as from that of the ass.

It is agreed that the different varieties of the European vine are variations of the same species slowly modified under the influence of man. This almost indefinite variation has not only resulted in advancing florescence and maturity and in differences in the quantities of tannin, sugar, and coloring matter in the fruit and other parts of the plant. Each of these external changes is in some way only the expression without of certain chemical changes. There appear to be as many kinds of coloring matters of seeds as there are varieties of grapes, and so different that some of them are soluble in water and some not; some crystallize, others remain amorphous; some precipitate the salts of lead in blue, and some in green. In a general way it may be affirmed, from M. Gautier's experiments, that each variety of vine has seen arise in it a new chemical species which would not have existed in Nature any more than the form with which it is associated, if man had not intervened. Man, therefore, in creating hybrids, not only makes new forms, but also throws into Nature chemical principles that had no place there.

The possibility of working in some species of animals the remarkable changes which skill has impressed on the plants of our fields and gardens can hardly be doubted. By depriving an animal of some one of the mineral principles that enter into the composition of its tissues, we should in all probability greatly modify its external form.

A single experiment is known to us which has been made in this direction by M. Chabry at the marine laboratory of Concarneau. He selected, as the animal to be experimented upon, the larva of the common sea urchin. It was seen, a few hours after it came out from the egg, as a point moving rapidly in the sea water. Observed under the microscope, it first appeared the shape of a

bell; later, it took a strange shape, which was not inappropriately compared to a lectern. M. Chabry even designated it by the Latin name *pluteus*, which means pulpit. As the time for this change of form approaches, there can be seen appearing in the tissues of the young larva a kind of calcareous needles, called *spicules*, the form and disposition of which are identical in all individuals of the same species. These spicules are composed of the carbonate of lime which the larva finds in the sea water, and which it absorbs as the roots of a plant absorb the potash contained in the soil. This lime traverses the tissues of the larva and collects for a time in them before settling in the half-crystalline figure of the spicules. It may be remarked that although they present a regular arrangement in the larva, the spicules have no relation, at least in the beginning, with the external form or the shape of the organs of the animal.

M. Chabry asked what would happen if he tried by raising the larvæ in water destitute of lime to prevent the formation of the spicules. The experiment was not without difficulties. It was necessary to prepare artificially a limeless sea water. With all the pains M. Chabry could take, in the light of the best analysis, the larvæ perished in the artificial water as soon as they were hatched. He then tried diminishing by degrees the proportion of lime in the natural water. This lime was the sulphate, and the experiment was directed, in order to prevent too radically changing the water, to substituting another base for calcium. Sodium was taken, because, it being already very abundant in the water, the slight addition of it which it would be necessary to make to replace the lime could not have any great influence. The results were very plain. Without any mixture of lime in the water, the just-hatched larvæ were arrested in their development and died in a few hours. If the elimination of calcium is not pushed to its extreme limits, and only a fifteenth part of the already very slight quantity contained in sea water is left, the larvæ will not be for forty hours distinguishable from those which are developed in normal water. At the end of that time the spicules should appear while the larva is assuming the form of the pluteus. But in water containing only a fifteenth of the normal calcium this change is not effected. Twenty hours later, in the sixtieth hour of their lives, the larvæ are still in the same condition, while those in normal water have spicules already branched, and their having taken the form of the pluteus is marked both by their shape and by the division of their intestine into distinct regions. The larvæ deprived of lime first exhibit this modification of the intestine toward the ninetieth hour, but they have no spicules and have not become pluteus. Their external form has therefore been profoundly affected by some change that has been introduced into the inner

composition of the tissues and the humors through the absence of one of their necessary constituents. The disturbance was not sufficient to cause the larvæ to perish or to stop the vital movement, but that had been diverted and had resulted in a new configuration of the living being. We have made a monster by a chemical process. No doubt a certain number of monstrosities besides those resulting from accidents that have occurred in the course of the development will eventually be attributed to a category of special changes like those which M. Chabry provoked.

A recent discovery has further cast a very striking light on that mysterious relation that connects the chemical constitution of beings with their external form. Aside from the serpents, only a few vertebrate animals are known that distill venom. On the other hand, notwithstanding the deep organic differences that remove the fishes from the reptiles, we find a few among them—the conger, the eel, and the sea eel—that have the appearance and almost the form characteristic of snakes. Prof. Mosso has lately shown that the blood of these fishes with the shape of a serpent is poisonous, even very poisonous. Half a thimbleful of eel's blood injected into a dog is enough to cause the animal to fall dead just as if it had been bitten by a rattlesnake. What is the connection between the presence of this poison in the blood of the eel and the shape of its body?

We may summarize in rigorously scientific language what we have just set forth by saying, with Chevreul and Charles Robin, that the form of living beings is a function of their molecular constitution. It is a point to which Darwin and his partisans of the transformist school have not perhaps given sufficient attention. Everybody now accepts these doctrines in their main features, but they have not taken into account, at least not fully, the factor of the influence of the medium. They have overlooked this chemical necessity which is imposed with every change of form or simply of color. We shall know, as M. Gautier has foreshadowed, the limits of the possible variations of an animal species when we learn how far it lends itself to the creation of new organic compounds. Even when there is nothing more than an exaggeration of a group of determined organs, a determining modification must be admitted in the chemistry of the individual. If media have been able to act, as everything indicates, it has been only by slow and progressive modification of the molecular constitution of the being, involving inevitably in its turn the changes of external configuration that determine each animal or vegetable species. The transformists show us with complete assurance vertebrated animals descended from some inferior animal, worm, or mollusk. Which? Here they cease to agree, and every one's preferences are suggested by this or that vague resemblance in

the disposition of the internal organs. But, if this were ever so much greater, there would still remain something to explain and something of importance. This vertebrate has muscles, organs of senses, viscera like the various animals from which it is supposed to have proceeded. But there are, further, in it living substances of a special order, cartilage and bone, which are real chemical species. When, how, and under what circumstances did these substances appear which we find identical as to themselves in all vertebrates which no other existing animals possess? It is not enough to show us this animal type proceeding from that other, that organ developing itself or disappearing or changing place and relations. We want to be told through what internal chemical actions these organic compounds appeared; those clearly defined substances the presence of which establishes an absolute distinction between vertebrate animals and the worms or mollusks from which they are supposed to descend.

Just as the appearance of new chemical compounds hitherto unknown was the necessary condition of the formation of new organic types, so it seems proper to suppose that at the beginning life on our planet appertained only to amorphous masses, which, in a prodigious succession of ages, after incommensurable periods, in consequence of an intimate working in their substance, were succeeded by existences the contours and dimensions of which were gradually and progressively defined. The sense of this necessity, doubtless, haunted M. Haeckel's imagination when he supposed that the *Bathybius* was the primordial jelly whence all living beings were derived.

On the other hand, this idea of a simple beginning of life was too far lost sight of by M. F. A. Pouchet and the later champions of the doctrine of spontaneous generation. It is not shown that the question of heterogeneity, which was so exciting thirty years ago, can ever be answered. In any case, it can not be revived under the form which its latest defenders have given it. Their chief error, from which all the others have been derived, was in wishing to overshoot the mark, in seeking to create at the bottom of their matrass, not substance having life—a bit of sarcode or protoplasm—but a being having a definite form. In the modern idea of the necessities of life, form appears to us as an epiphenomenon resulting from infinitely numerous and infinitely progressive circumstances. To sum it all up, form is pre-eminently a hereditary characteristic. It can exist, we can only comprehend it as slowly acquired by a process of modeling a thousand and a thousand times secular. It was this form, this figure, that the partisans of spontaneous generation thought they brought forth in their apparatus! The objection we raise here, very curiously, was never made to them, and their theory was only ruined by

detail, by the production of facts undermining their experiments, but which did not touch the foundation of their doctrine. No one will ever cause to appear in a vial, by combining all imaginable elements, a microscopic animal or plant, however simple, with a definite configuration, because that requires duration of existence behind it. The problem to be solved is not there. The necessary thing is to create that unknown molecular movement which alone constitutes life and which brings on all the rest.

At the present time chemists seem to be on the point of obtaining by synthesis substances similar to those of which some of the important parts of animals and plants are made; but we must not nourish a chimerical hope too rapidly. There is a chasm between the end almost reached by M. Schützenberger and others, and the creation of the smallest parcel of living matter. One may make albumin like that of an egg, fibrin like that of the blood, but he will still have inert substances, as they are. The white of an egg is not living, although it emanated from a living being, no more than the shell and the greater part of the yolk. It is simply a secretion—an outthrow of the living flesh of the hen—and which acquires from it nothing more than a composition nearly identical with it, and in any case extremely complex. Hence the difficulty of reproducing artificially a similar body by the synthesis of the very numerous chemical elements that compose its delicate structure. Every molecule must be there and in its place. Even when this synthesis has been performed in his retorts, has the chemist produced life? Not at all! He will be like Prometheus in the face of his clay statue; the fire from heaven will be wanting—the living fire. That albumin, that fibrin, the issue of the combination of any number whatever of the different elements that should compose it, remain inert substances.

Yet the thought of producing living matter does not seem entirely hopeless. The conditions have already necessarily been realized on the planet, and perhaps many times. It is not impossible that at the bottom of the ocean or in stagnant waters sarcodic masses are still taking spontaneous birth. We have no evidence of it, but such a phenomenon does not appear liable to the fundamental objection. How shall we surprise this beginning of life? If science shall ever succeed in achieving this great work in its laboratories it will have accomplished the desire of the first man of the Mosaic legend. We shall know what life and death are. The dream of the heterogenists will be realized, and man will indeed have created life.—*Translated for The Popular Science Monthly from the Revue des Deux Mondes.*

ON ACCURACY IN OBSERVATION.*

By H. LITTLEWOOD, F. R. C. S.

THERE are many theories afloat to solve the great question of medical education—what subjects should be taught in the early part of the curriculum, and what left out. I do not think it is quite such a great matter what is taught: how it is taught is of far more importance. For I take it that there is no training which can turn out a medical man who is up to date in every branch of his profession, and very thankful I am that there is no place in the world for such a prodigy. He would be very like a historical character described in one of George Eliot's novels: "The simplest account of him one sees reads like a laudatory epitaph, at the end of which the Greek and Ausonian Muses might be confidently requested to tear their hair, and Nature to desist from any second attempt to combine so many virtues with one set of viscera." To hear some men, and even medical men, talking, one might almost suspect that we had found the realization of such a description. The great aim and object of medical education, and, in fact, of all education, is that it should make you accurate observers; and any plan or scheme of education that has not succeeded in this has been a failure, even if, after years of study, you can write the whole of the letters of the alphabet after your name. You hear people talk of education, and of So-and-so going to this or that school or university, either at home or abroad, *to finish* his education. Never was there a more mistaken notion. The word "education" should almost be used like the word "eternity." It must go on as long as humanity exists. What you should be doing at your school and university is to train yourselves to observe things accurately, so that you may rightly interpret their meaning. Let me tell you it is a very difficult thing to be accurate. You will, I am sure, forgive me for again quoting from George Eliot, but she has so well expressed what I want to say: "Examine your words well, and you will find that, even when you have no motive to be false, it is a very hard thing to say the exact truth even about your own feelings: much harder than saying something fine about them which is not the exact truth." If such is the case, we can not be too laborious and painstaking in order to eliminate error. If your early studies in chemistry, biology, anatomy, physiology, etc., have been rightly conducted, you should have learned to note facts and to make careful observations; and you will find this training invaluable when you begin your hospital work, as also during the remainder of your

* From an address delivered before the Yorkshire Medical Society, on October 18, 1893.

medical lives; for the whole art and science of medicine must be founded on accurate observation. All careful students of medicine should be good and accurate note-takers; the practice of sketching and making diagrams of the things you are observing is a very valuable one to cultivate. In taking notes on your cases acquire the habit of putting your observations on paper while you have the patient before you; compare the diseased or injured part with the corresponding healthy part; and if both similar parts are affected, you must compare them with what you have learned to consider as a healthy ideal. If records are not made at the time they lose somewhat of their value, even if they are made within a few hours after the appearances observed have been described; but if left days or weeks—and I know this is sometimes the case—the imagination is left to fill in the details; and should they be left for a much longer period, it is perfectly astonishing what may not be described as facts, especially if the writer is anxious to make the accounts read well. I believe this is the reason why there is so much doubt about so-called facts; a good many of them are not facts at all, but merely expressions of a very fertile imagination. There is more truth in some of the stories of the Arabian Nights. A certain part of what has been called the new criticism of some ancient writings and records consists in trying to ascertain how soon after seeing these events did the eyewitness write the records. Of course a good deal of the value of these records depends upon the decision of such a point—how much and how little has the imagination taken part in the evolution of these so-called records of well-authenticated facts? Then, in describing your cases, do not use language that lends itself to exaggeration. Whenever you can put down actual measurements and actual figures it is much better to do so.

According to the statistical tables of some operations and new methods of treatment one finds all the cases, or a large majority of them, classed under the heading of "cured." This is a very unfortunate word, for it appears to have a variety of meanings; and what one person understands as a cure certainly would not come up to the standard of another. I often wonder if the notes of some of the failures have not been lost or if the cases of failure have not been removed, because, for some reason or other, they do not quite come within the category of the title-heading selected for these tables. We do not find many statistical tables of failures. When one reads these accounts one wonders if they were written for the purpose of finding out the truth, or was there some other motive? Macaulay, in his essay on Gladstone on Church and State, has a passage which I think I may aptly quote here: "It seems quite clear that an inquirer who has no wish except to know the truth is more likely to arrive at the truth

than an inquirer who knows that if he decides one way he shall be rewarded, and if he decides another he shall be punished." But as students your first object must be to be accurate. I will give you one or two examples of curious notes that I have seen lately made by some students. I was reading an account of an operation I had performed the day before, and, finding not a single statement in the note was quite accurate, I asked how it was that such an account had been written. The student excused himself by saying that he had not seen the case, but had gathered from another that I had done exactly what he described. In another example, from some notes on two cases of suprapubic lithotomy undertaken on the same day (and these were written by an eyewitness), I was startled to read in both the accounts this passage: "The peritonæum was then opened." I need hardly say that this statement was pure fiction. I quote these examples to show you that I am not exaggerating; I am sorry to say I could multiply them. Of course you will all agree with me that notes of this kind are infinitely worse than no notes.

Now, how is it that it is so difficult to be accurate? I think accuracy means a careful training of all one's faculties, and this is so often neglected. It is so much easier to let other people think for us than it is to think for ourselves. A medical man who has not acquired the faculty of thinking and interpreting for himself has missed his vocation. I have sometimes heard students remarking on the physical signs of a chest, that such and such parts are dull on percussion, or that there was a cardiac murmur heard at a certain part of the chest because Dr. B. had said so, and not because the speaker had appreciated the differences of sound. You must learn to appreciate these things for yourselves by trying to test them by your ideal normal standard; and until you have actually heard, seen, or felt them, these things can not be said to exist as far as you are concerned. The eye only can see what it brings with it the power of seeing. When you first look down a microscope everything looks indistinct, a mass of pretty coloring; then, after training, certain details are observed—nuclei, nucleoli, fibers, cells, etc. After carefully studying the detailed structure of an organ you can recognize it the next time you see it; then, knowing the different elements of which it is composed, you can recognize if it is a specimen of a healthy organ or if the organ is in any way diseased. The trained eye is able to see endless minute differences where the untrained eye discerns nothing. Things look very hazy and indistinct in the first gray of the early morning; every day of your lives adds some new facts, some new observations, and each day brings you nearer the brightening sunshine of a more extended knowledge, until some of you may be fortunate enough to realize the

lofty ideal of Prof. Huxley: "Education promotes morality and refinement by teaching men to discipline themselves, and by leading them to see that the highest, as it is the only permanent, content is to be attained, not by groveling in the rank and steaming valleys of sense, but by continually striving to those high peaks where, resting in eternal calm, reason discovers the undefined bright ideal of the highest good—a cloud by day, a pillar of fire by night." We do not all see the same differentiations of color or appreciate the varieties of taste, smell, or touch, or hear to the same extent the infinite variety of musical expression; and it is only by cultivating our senses that they can be improved. About a year ago, at the Ida Hospital there were some very offensive smells. Everybody thought there must be something wrong with the drains, until the resident, Mr. Wilks, discovered a horribly offensive fungus. I requested him to bring some specimens to the infirmary weekly board meeting, and I was very much interested to hear what the different members would say. The first to examine it said that "it did not smell at all"; the second that "it was not so bad"; but all the other members agreed with me that it was horribly offensive and quite accounted for the bad smells. I mention this as an example of differences of opinion about a fact as to whether something was or was not offensive, and to illustrate that we do not all appreciate sensations to the same extent. You are all of you familiar with the curious phenomenon of color-blindness; but there is a much more common and not so easily detected form of blindness which has received the name of "intellectual blindness." We all suffer from it more or less; some to such an extent as to be almost like unto an ancient description of some heathen gods, "who have eyes and see not, ears and hear not, noses have they and they smell not." You have all of you been struck with the fact that there are certain things we see every day, yet all at once we discover something in them we have never noticed before. I venture to predict that, if I gave all of you a piece of paper and asked you to write down the exact figures as they appear on the face of your watches, not one tenth of you would put them down accurately—i. e., of course if you have not already tried the experiment—and yet all of you have seen your watch faces several hundreds of times. Or, if you like to make the experiment of getting half a dozen eyewitnesses to describe something they have seen, it is more than probable we should find very marked differences in their descriptions. I think you will agree with me that some of the descriptions in the daily papers bear out this contention. You often have your mistakes pointed out to you before you are conscious of their existence. You must have very clear ideas of the anatomy and physiology of a human being in a healthy condition before you can

become accurate observers of disease. This knowledge can only be obtained by diligent work in your dissecting rooms and laboratories; there is no royal road to it. Do not forget that you are all disciples of William Harvey, John Hunter, and Charles Darwin.

To sum up in one short sentence. Your observations will consist in comparing your ideal standard of the normal with any conditions you consider to be aberrations from that type. Then, having made your observations, the next thing you have to learn is to arrange them in their proper proportional perspective and to rightly interpret their true significance. Given certain altered conditions, how have they been produced? What have been their antecedents? Prof. Huxley has called the interpretation of these facts "retrospective prophecy." In his book called Science and Culture there is an interesting address entitled After the Method of Zadig: Retrospective Prophecy as a Function of Science; and as this method is one which you as students will largely adopt I will venture to read to you the story of Zadig. It is very doubtful where this philosopher lived. Babylon claims him; but he appears to have forsaken this city to live on the banks of the Euphrates, where he could be alone with Nature to investigate and unravel her mysteries.

The story is briefly this: The chief eunuch having been sent in search of the queen's dog, which had been lost, met Zadig, who had seen the markings on the sand left by the straying animal, and from this was able to give almost an exact description of its appearance. Later on the grand huntsman came the same way looking for one of the king's horses which had been lost, and Zadig, having noticed the marks on the sand and the disturbances among some trees through which the animal had passed, was able in like manner to describe it. As neither of the animals could be found, Zadig was accused of having stolen them; he was taken prisoner and brought before the court, and sentenced to transportation. No sooner was the sentence passed than the missing animals were found, so the judges had to reverse their sentence, but fined him four hundred ounces of gold for saying he had seen that which he had not seen. After paying the fine he explained to the court how he had been able so exactly to describe the animals; from this his fame spread widely. The king commanded that the gold should be returned to him; this was done, but three hundred and ninety-eight ounces were retained by the court for legal expenses, etc.

You will be saying, But, after all, this method is only applied common sense; but let me tell you that it is a very great advance on certain other methods which have been adopted by the so-called wise men through the ages. It is not so long ago that

witches were burned because the death of some pigs was thought to be due to witchcraft. Nowadays, probably, the cause of death would appear in the death certificate of those pigs as swine fever; and many of the so-called haunted houses, by the method of Zadig, have been proved to be haunted, not by the ghosts of the departed, but by bad drains. Children often adopt, quite unconsciously, the method of Zadig. I had a good illustration of this last Sunday, and I must tell you about it. Talking to a blind child in the children's ward, I asked her if she knew who I was. She said at once, "Yes, the doctor." I asked her how she knew that. She answered again, "Oh, nurse always says 'Hush' when the doctors come into the wards."

Now, gentlemen, if you really enter into the true spirit of medical work, you will very soon train yourselves to be accurate observers, and from observing human beings you will soon be tempted to investigate and delight in other natural phenomena, to find out your own proper place in this great cosmic system, of which you are only a unit or microcosm. There is no doubt that a true student of Nature has provided himself with endless sources of amusement and happiness. Some of you may remember the lines of Longfellow on the fiftieth birthday of the great naturalist Agassiz:

"And Nature, the old nurse, took
The child upon her knee,
Saying, 'Here is a story-book
Thy Father has written for thee.'

"And he wandered away and away,
With Nature, the dear old nurse,
Who sang to him night and day
The rhymes of the universe.

"And whenever the way seemed long,
Or his heart began to fail,
She would sing a more wonderful song,
Or tell a more marvelous tale."

And this is the heritage of all honest students of medicine who have built up their life's work on accurate observation.

THE largest diamond in the world, the Excelsior, was discovered on the 30th of June, 1893, in the mines of Jagersfontein, Cape Colony, by Edward Jorgansen, inspector. It is a stone of the first water, valued at about five million dollars. It was carried to the Cape under the special convoy of a squadron of lancers, and shipped on a gunboat to London, where it was deposited in the Bank of England. It weighs nine hundred and seventy-one carats and three quarters, or two hundred and five grammes and a half.

THE PHOTOGRAPHY OF COLORS.

By M. LAZARE WEILLER.

IT is difficult to give a simple explanation of color. Physicists declare that it is the result of a vibratory movement; and metaphysicians who listen to them pretend to comprehend this. Although it is not clear, this definition is nevertheless the only one it is possible to give. There exists a vibratory movement which is translated into heat, light, and electricity. There are possibly also movements that determine the various psychological phenomena—other vibrations no less confused, no less vague, no less mysterious to our minds than the physical vibrations.

Many persons will be surprised when they are told that M. Lippmann, the discoverer of photography in colors, was never engaged in photography. He discovered in the play of luminous vibrations what he was trying to define in the theory of sonorous vibrations. Being charged with the exposition in his lectures at the Sorbonne of the principles of acoustic phenomena, he sought especially to demonstrate to his students that the pitch of the sound given out by an organ pipe depended on its length and not upon the particular metal of which it was constructed. He was at once struck with the results that might be drawn from this phenomenon; he asked if it would not be possible to transport into the domain of light the curious property that seemed to be involved in that of sonorous vibrations. This conception, in its elegant simplicity, might be said to be a conception of genius. There was nothing in it like the attempts that were made earlier in the century to fix colors photographically. The first experiment in this direction was made in 1810 by Prof. Seebeck, at Jena. He tried to impress the colors of the solar spectrum on a paper covered with a film of chloride of silver. His experiments, though not successful, were much talked about. They were taken up again in earnest in 1841 by Sir John Herschel. Failing with chloride-of-silver paper, he tried bromide and iodide of silver, and natural products, such as guaiacum root. He succeeded by some of these processes in temporarily fixing a few colors on sensitive papers. Such results were encouraging. We were then at the beginning of photography. But these successes were soon surpassed by the experiments of Edmond Becquerel, who succeeded, in 1848, in obtaining upon a silver plate covered with a film of violet subchloride of silver the impression of all the colors of the solar spectrum. Unfortunately, the colors stored up in this manner vanished as soon as the plate was exposed to the light. All attempts to preserve them by means of a fixing bath failed. At every effort the color disappeared. The impression of the spectrum colors by the

Becquerel process lost most of its value by its instability. The science and experimental skill of the celebrated physicist could not overcome this obstacle, on which all who tried to accomplish photochromy by the method of direct impression were successively wrecked.

The chemists Niepce de Saint-Victor, 1851 to 1866, Testud de Beauregard, in 1855, and Poitevin, in 1865, tried to secure the colors by means of chemical substances, but were never able to fix their proofs, or to keep them perfect in the presence of light. After the chemists came the photographers; after the photographers, the men with empirical methods. Then came incomplete geniuses, like Charles Cros, reproducing the colors by superposed prints, without using a direct method, or any effective one. Yet Cros was wonderfully endowed with inventive genius. He had notions about everything. He was one of the first persons, if not the first, to dream of phonography. He occupied himself with the transmission of images to a distance. Occasionally he satisfied himself also with inventing things of a simpler and more positive character, such as his famous paste, a little microscopic box of which would afford ink enough for a whole lyceum for an entire year.

What no one could obtain by any chemical method, M. Lippmann has realized from the theory of vibratory motions. In the soap bubbles, with which every one is familiar, colors of rare brilliancy detach themselves from the thickness of the liquid films, which are themselves colorless. Whenever a transparent body is drawn out into a very thin film it appears with iridescent hues, although it may be made of a colorless substance. The coloration arises from the fact that the light reflected from the two faces of the film has not passed over the same distance. In other words, the light plays by its reflection upon the two planes that bound the film. The result is that the light-rays cross each other and give rise to a phenomenon which is called interference. On closely examining the brilliant tints of the soap bubbles we easily recognize the different colors of the spectrum.

Newton first discovered the causes of coloration, and, to render them more tangible, he devised the experiment of "Newton's colored rings." On an absolutely plane glass he fixed, by its spherical face and without fastening it in any other way, a convex lens; the lens, consequently, did not touch the glass except at one point, all the other points remaining separated from it by sections of air which grew thicker as they were farther removed from the point of contact. When this apparatus is illuminated by a monochromatic light, such as the yellow light given by a lamp burning salted alcohol, there is at once remarked a central black spot on the glass, surrounded by concentric rings alter-

nately bright and dark. These rings are not equally distant from one another; they center at the point of contact of the two glasses. By employing simple lights of different natures we can see the diameters of the rings increase or diminish according to the different wave-lengths of the lights used. It appears, therefore, from this experiment that if we illuminate the glass with white light we shall have the superposition of the effects obtained with different simple lights. In such case the colors can not coincide, and then, instead of having a system of alternately dark and light rings, we shall have rings iridescent with all the colors of the rainbow; and this is precisely what is produced in the soap bubble. The important fact in the phenomenon is that the color varies according to the thickness of the film. In this experiment we are dealing with natural colors, produced without the intervention of any chemical action, but simply by a series of luminous phenomena which we shall shortly explain. M. Lippmann's invention rests upon this principle.

If you blow out a soap bubble it reflects violet as it issues from the pipe; then, becoming larger—that is, the film becoming thinner—it reflects blue, then green, yellow, and finally, when the film has reached its thinnest, red. In this experiment we can perceive what is the real origin of colors. They are only the successive notes of the luminous gamut, as musical notes are formed by the gamut of the scale of sounds. Newton arbitrarily counted seven colors in the spectrum, so that he might make it display as many colors as there are principal notes in the musical scale.

Like sound, light is propagated by undulations through space. This transmission of vibratory motion is carried on with great swiftness, passing through the distance from the sun to the earth in eight minutes. Aside from the difference in velocity, light-waves are like sound-waves. The simple colors are for light what musical notes are for sound. In this way Fresnel, in his theory of undulations, explains the difference in the coloring of the different parts of the spectrum.

Every sound is caused by a vibrating body engendering waves which reach our ear and produce the sonorous sensation in it. But all sounds are not identical. Every one can distinguish an acute note from a grave note. In studying the characters of acuteness and gravity of sound, the conclusion has been reached from experiment that the sounds emitted by a vibrating body are higher the more rapid the vibrations, or the more there are of them in the same time. Each length of wave corresponds to each sound peculiar to it, and is in inverse proportion to the number of vibrations. Since the acute sounds result from the more numerous waves, their waves are shorter and closer than

those of the grave sounds; for they all have the same velocity of progress, and reach us in the same time. The melody and harmony are heard simultaneously, whatever the distance of the orchestra. The exact sensation of the piece played is felt on every side—a thing which could not take place if the high tones of the violins and flutes were transmitted more rapidly than the grave sounds of the violoncellos and contrabasses. It being thus possible to assimilate simple sounds with simple colors, we have to suppose that the number of vibrations determines the color. A luminous point produces, to emit the various colors: red, 497; orange, 528; yellow, 529; green, 601; blue, 648; indigo, 686; and violet, 728 trillion vibrations per second. Each color corresponds with a luminous film of variable thickness. The thicknesses of the several films representing the simple colors—or, what are the same, the wave-lengths of these colors—are: red, 620; orange, 583; yellow, 551; green, 512; blue, 475; indigo, 449; violet, 423 millionths of a millimetre. Red, we thus see, corresponds to the grave notes and violet to the acute notes of the musical scale. To obtain an idea of the thickness of the films corresponding to the different colors, we might take as a standard for comparison a sheet of common paper, which is about a tenth of a millimetre thick. Two hundred and fifty thicknesses of the violet film would have to be laid upon one another to produce this thickness, and one hundred and sixty of the red.

In order to explain the cause of the complex colors of natural objects we may again have recourse to the properties of vibrating motions, which, like those of the phenomena of sound, can be placed one upon another. Thus, when a cord is stretched over a sonorous box, like the string of a violoncello, we can make it all vibrate; its ends will be motionless, while the middle will vibrate with the maximum amplitude. The motionless extremities are called nodes, and the middle is a belly. We can also draw the bow across this cord in such a manner that, while vibrating as a whole, the two halves of the cord will each vibrate on its own account, following a law of individual vibration. Under these conditions a superposition of two vibratory movements is realized—that of the whole cord and that of the two halves vibrating separately. There results a complex sound formed of the fundamental sound and the superposed harmonic. It is this superposition that gives to the ear the sensation of the *timbre* of different sounds; the phonograph, with which everybody is acquainted, is based on this principle. The vibrations of a single membrane can reproduce several superposed vibratory movements, and thus register human speech.

Most of the complex colors, such as rose, maroon, or the various tints of green, can be formed in the same manner. They

may result from the superposition of several simple vibrating motions. In general, the coloring of bodies results from the diffusion of the light-rays which illuminate them. The bodies absorb a part of the rays and reflect others. The mingling of the reflected rays produces on the eye the impression of a definite tint. A cloth appears red to us because it reflects chiefly the red light and absorbs all the other colors. If it reflects all the solar rays as they are, it appears white to us; if, instead of reflecting them, it absorbs them, it appears black.

The origin of colors, therefore, we see, depends upon a physical or mechanical and not on a chemical cause. The white light which comprises them all is only the resultant of the infinity of the colors that exist and succeed one another in gradation from the red to the violet. This may be easily perceived by letting a ray of sunlight pass through a crystal cut in facets.

To comprehend fully the direction of M. Lippmann's thoughts before hitting on the photography of colors by the application of the theory of vibratory motions, we must say a little more concerning the phenomena of interference. When two sound-waves meet, there occurs, according to certain specific conditions, either an amplification of the sound by their combination or a destruction of it by their collision. The principle of the interference of sound was demonstrated by Colonel Napoleon Savart in 1839, by an experiment which is not so well known as it should be. This sagacious officer placed in front of the principal wall of the citadel in which he was garrisoned a bell which he rung by striking it with a hammer. The bell thus became the center of a direct wave which was propagated to the wall of the citadel and reflected from it. In other words, the action of the sound was brought to bear upon the wall, which sent it back to the starting point and thus could give rise to the phenomenon of interference. Some among the soldiers stationed along the line between the bell and the wall observed a distinct re-enforcement of the sound; while others, placed exactly at the points of interference, heard nothing.

What passed in Colonel Savart's experiments is reproduced in the same manner with light-vibrations. Just as sound added to sound may produce either silence or amplification of the sound, so light added to light may produce darkness or amplification of the luminous effect. When direct light falls upon a mirror, it meets on the way the light that was previously reflected, and wherever the vibrations agree in direction the brightness is increased, whereas it is extinguished wherever they are opposed to one another. The space in front of the mirror will therefore be divided into successive sections or stratifications. In some, the light will be of its highest brightness; in others, on the other hand, there will be complete darkness. It can easily be deter-

mined by calculation that the distance between the sections is about one four-thousandth of a millimetre; and it is hence conceivable that, the naked eye not being able to take in such small intervals, the sensation is one of a uniform light. But while the naked eye is impotent, the photographic plate is not. So M. Lippmann thought, when he conceived the idea of utilizing the phenomenon of interference to produce, not in the open air, but on the sensitive photographic plate, the stratifications formed alternately by the luminous and dark lines. By this process the luminous impression of the object photographed will appear only on the sections where the light is bright, while no action will take place in the dark strata.

If, then, we seek to reproduce photographically a body of many colors, each of these colors will find in the thin sections determined by these stratifications the place corresponding to the thickness of each of them. Red will find sections of six hundred and twenty millionths of a millimetre, and violet sections of four hundred and twenty-three millionths of a millimetre, to correspond to the thickness of the luminous stratum producing these colors. So with all the other simple colors, and consequently with the constituent parts of the complex colors. In developing the sensitive plate thus impressed, its thickness will be formed of a series of leaves of photographic silver, separated from one another by distances infinitely small and differing exactly according to the color which has impressed the plate placed behind the objective. We understand, then, that those leaves constitute precisely the organ of reproduction of colors, without which they would have to be colored by themselves. In practical operation it is necessary to prevent any object in the photographic stratum from hindering the fixation or accumulation of the colors in these virtual sections, which are to produce the colors by reflection as the liquid films of the child's soap bubble produce them.

It is necessary, therefore, before everything else, to exclude the ordinary bromide-gelatin or chloride-gelatin plates of commerce, the sensitive coating of which is the result of an emulsion. When examined with the microscope, this washing usually exhibits a very coarse grain derived from solid particles of perceptible matter, which are of considerable dimensions in proportion to the wave-length of a color-stratum. They obstruct that stratum completely, deform its reflecting planes, and prevent all communication of chromatic phenomena. These plates could no more produce the thin strata corresponding to the colors to be photographed than a stone sixteen feet thick can be worked into a wall of three feet. The plates of commerce are, besides, usually opaque and can not be traversed by the direct wave and the reflection wave which are to produce the phenomenon of in-

terference. Sensitive collodion or albumen plates, which have the advantage of being continuous and transparent, are preferable. This choice of processes in sensitizing is, however, not absolute. The pre-eminently important point is that the sensitive plates have no grains, or that the grains be of negligible size—that is, of dimensions inferior to half the length of wave that corresponds to the color.

Without going into operative details we can easily represent to ourselves the process employed by the inventor of the photography of colors to render his invention practicable. The reflecting face of a plane metallic mirror is covered by the usual process of sensitizing with an impressionable stratum of albumen or collodion and chloride or bromide of silver. If a light-ray of any simple color is made to act upon this, it occupying, consequently, a determined place in the gamut of simple colors, there results that the incident rays will traverse the sensitive and transparent stratum, will be reflected on the polished surface, will return backward, and will meet on their return the rays that are coming. There will then be formed two luminous waves—a direct wave and a reflected wave—and these, meeting, will produce interferences. We shall see that what is created in the projection of these luminous rays is only the repetition of what was produced in the experiments of Colonel Savart by the projection of the sonorous vibrations on a wall.

In the photography of colors the space in front of the mirror is filled with parallel planes alternately bright and dark, in such a way that every two of the bright planes are separated from one another by a distance equal to half a wave-length—that is, to the four-thousandth part of a millimetre. There results from this the creation of a large number of these planes in the thickness of the sensitive stratum. In short, this sensitive coating, already very thin, is divided, as the sheet of paper we have mentioned would be, into a number of layers infinitely thinner.

Only the brightest planes could impress the sensitive layer, and in the course of photographic development this impression will be revealed in a black color, while the sections corresponding to the dark planes will not be impressed. If, then, employing the process of ordinary photography, we dip the developed plate into hyposulphite of soda, all the matter sensitive to light and not changed will be dissolved in it, and there will persist on the plate only the infinitely thin sections of reduced silver, and those at the points where the bright planes had fixed themselves. Therefore, the whole thickness of the photographic stratum will be divided into sections by planes of metallic silver parallel to one another and separated by a distance equal to half a wave-length of the simple color which has impressed the plate. These planes,

then, constitute, in pairs, a thin film the thickness of which is precisely that indicated by Newton's theory of the rings; and thus, according to that law, of which we cite the text, the rays reflected upon these two films give, by interference with one another, the sensation of the corresponding color. Furthermore, each color produces in the plate a similar system of parallel planes, the coexistence of which explains the photographic reproduction of the compound colors. The whole secret of the photography of colors lies in the enunciation of this principle.

On observing the reflection of the plate fixed and dried by the process which we have indicated, we shall discover upon it the direct reproduction of all the colors which have been presented before it. The time of exposure plays an important part in the practical execution of the experiment.

The beginnings of the experiments were very laborious. The first effort was to photograph a spectrum, in which the red was extremely inconvenient. The chemical activity of the rays of this color is very slow. They impress the plates so weakly as to permit photographers to use red light without danger while developing their gelatinized bromide-of-silver glasses. Even those least familiar with photography know that red objects are reproduced in black on the positives, and that means that they have not impressed the negative plates, however sensitive. While the red shows itself very slowly on the sensitive plate, the blue and the violet act upon it with great energy, and completely polarize it if the exposure is allowed to continue during the time required to secure the impression of the red. Means, therefore, had to be found to let the exposure to the red be continued for a long time, to the green for a little less long, and to the blue and the violet for a very short time. It is not hard to conceive the trouble which these difficulties, all material, caused at the beginning of the experiments. In fact, they were susceptible of barring the way to every new tentative in the art of practically photographing colors.

How should one proceed in photographing a human being or a landscape? A posing before the objective as many times as there were colors could not be thought of. It would, besides, be necessary to fix the person in the same place, to make him resume the same attitudes—conditions which would make the faithful reproduction of his image impossible. The assistance of a practical photographer became necessary in this emergency.

M. Attout-Tailfer discovered that on plunging an ordinary plate into cyanine, its sensitiveness increased for the red and diminished for the violet, in such a way that by successive applications it was possible to equalize the sensitiveness of the plate for the different regions of the spectrum, and therefore for the dif-

ferent simple or complex colors. This is what is called isochromatism.

By the aid of these improvements M. Lippmann has succeeded in fixing on his plates images of marvelous beauty. The colors have an inconceivable brightness and delicacy of shading. They have nothing in common with painted copies of photographs, which simply enhance the photographic images with coloring. The photographic proofs obtained by M. Lippmann have a strength of coloring and a richness of tone which no water-color picture has ever attained. This is because, in his photography, the registration of the color is combined with the accumulation of all the colored rays.

It is not necessary to say that the learned professor in the Sorbonne has not sought to draw an industrial profit from his invention. It is free to all who may hereafter wish to direct their investigations that way. There remains much still to be done before all the improvements can be given to science. The problem now is to advance from the fixation of the colors on the sensitive plates to their reproduction on paper. Theory permits the prediction that regular reflection by a metallic mirror may be replaced before long by the diffusion of light over a dead surface. It is, then, permissible to hope, without contradiction of the theory of interferences, that the multiplication of proofs by simple printing on paper is only a matter of time. It is easy to understand how much the arts and science are interested in the progress of the photography of colors.

While the pigmentary colors used by painters are made of substances which light may change in the long run, interference colors, which are produced by the vibratory movement alone, depend solely on the physical and mechanical conditions of the experiment, and are not subject to alteration by time. Photography of colors will permit the faithful reproduction of the pictures of the masters, and will also assure the reproduction of meteorological phenomena which may be of considerable importance in future studies of astronomical science.—*Translated for The Popular Science Monthly from the Revue des Deux Mondes.*

A PRACTICAL course of instruction in psycho-physiology was given in University College, London, during the Easter term, by Dr. L. E. Hill. The plan of the course was to take the student methodically over the several senses, and familiarize him with the methods by which the new branch of science known as physiological psychology or psycho-physics determines the precise manner in which sensation varies, both quantitatively and qualitatively, with variations of the stimulus, of the particular portion of the sensitive surface stimulated, etc. The Athenæum acknowledges the backwardness of England as compared with the United States and Germany in the systematic laboratory instruction of students in this subject.

SKETCH OF WILLIAM MATTIEU WILLIAMS.

WHILE the characterization by Mr. Thomas Laurie of W. Mattieu Williams as having been "the first who swept aside the veil that had been hung up between scientific workers and the toiling millions" can hardly be verified, it is an indisputable fact that he was eminently successful in presenting scientific truths in a form acceptable to the common people and adapted to awaken their interest; and his presentations rarely failed to suggest further thought on the subject to which they related.

Mr. WILLIAMS was born in London, February 6, 1820, and died in London, of cerebral apoplexy, November 28, 1892. He was taught in boyhood, at three schools of the kind that then flourished, a little arithmetic, grammar, geography, and Latin, but no science. His experiences even thus early set his mind in the train which led him to the adoption of those views on education which he advocated and on which he acted later in life. When fourteen years old he was apprenticed to Mr. Thomas, mathematical and optical instrument maker at Lambeth, where he gained a practical skill and scientific knowledge which he was able to turn to good purpose in the several courses of scientific lectures which formed part of the work of his mature life. Although he had to work from seven o'clock in the morning till eight o'clock at night, he continued to attend the night classes of the London Mechanics' Institution, Southampton Buildings, now the Birkbeck Institution; and during the whole term of his apprenticeship he attended the biweekly lectures which were given by eminent men of the time in their several specialties, and the classes in mathematics, chemistry, natural philosophy, French, German, and phrenology, and took part in the exercises and discussions of the literary societies. The programmes of those societies during the period of his attendance upon them afford as among the subjects of papers contributed by him the Relative Character of the French and English; Constantinople and the Turks; Dreaming, Phrenologically Considered; the Expediency of Railways becoming National Property; the National Characteristics of the French; Direct and Indirect Taxation; the Propriety of Discussing Political Questions at Mechanics' Institutions; and topics related to psychology and phrenology. On coming of age he obtained possession by inheritance of a small sum of money, by the aid of which he studied chemistry at the University of Edinburgh and made a pedestrian tour of two years in Europe. He spent much of the time in Switzerland, Italy, Greece, and Turkey; and, becoming acquainted with the Turk in the last country, found him a better man than he was generally regarded as being, and a person of

better possibilities. After his return from the Continent he was elected a member of the Committee of Management of the London Mechanics' Institution. He opened rooms for carrying on commercially the business of an electrician, an electrical instrument maker, and electrotyper, intending at the same time to deliver lectures on science and travel. But as his friend Mr. John Angell remarks, in a memoir prefixed to his Vindication of Phrenology, "his enthusiastic love of science and general research was destined to become a foe to the habits and forms of attention required in successful commercial business. Many a time friends calling on him late in the evening found him so thoroughly absorbed in pursuing the theory of some practical problem he had succeeded in working out that he had forgotten, meantime, that he had taken neither food nor refreshment since his morning breakfast." He was frequently called on to lecture at institutions at a distance, when he would be absent for days at a time, chiefly on subjects connected with his European tour, among which a favorite course with him was one of six lectures on Switzerland, its social and historical aspects, physical geography, geology, and glacier formations.

About the year 1846 Mr. William Ellis made an offer of one thousand pounds sterling toward establishing a school, to be called the Birkbeck School, on the premises of the London Mechanics' Institution, in which, besides the principles of the natural sciences, the principles of social well-being, or of social and political economy, should be regularly taught. The Committee of Management of the institution were unfavorable to this plan, and ignored it in their report; whereupon a bitter controversy ensued, in which Mr. Williams was active in opposing the course of the committee and insisting on giving a hearing to Mr. Ellis's proposition. Finally, the offer was accepted over the heads of the managing committee, the project was put under the care of a special committee, and the first Birkbeck School was established July 17, 1848, with Mr. John Rüntze as head master. Many years later Mr. Williams met one of his strongest opponents in that controversy, who confessed to him: "We all thought you and your party were wrong; now I know that your party was right and we were wrong."

The Birkbeck Institution was successful from the first, and attracted the attention of George Combe, a man distinguished for his advocacy of schemes for bettering the condition of man, and who had become acquainted with Mr. Williams while he was studying in Edinburgh. He determined, with the aid of money which Mr. Ellis should furnish, to establish a similar secular school in Edinburgh, in which phrenology should be taught in addition to the other branches. The problem of finding a com-

petent and suitable teacher for such an institution presented itself and might have occasioned considerable difficulty, had it not been solved by Mr. Williams offering to undertake the headmastership. It was therefore called the Williams Secular School, and was opened in the Trades' Hall, December 4, 1848. It increased rapidly, and was soon removed to the larger premises which had been occupied by Dr. R. Knox's anatomical school, where it continued "doing invaluable model work" until Mr. Williams was called, in 1854, to take charge of the Birmingham and Midland Institute.

This institution was projected by a few leading men in Birmingham, and was incorporated by an act of Parliament of July, 1854. Mr. Williams was invited by the Council, on the recommendation of Mr. Lionel Playfair, now Lord Playfair, to become master of the science classes. He gave an introductory lecture, August 17th, which at once aroused interest, and was commended by the press as the work of "a man of no ordinary ability." In this lecture, Mr. C. J. Woodward says, in his account of the institute, "Mr. Williams pleaded for the application of science to industry, and pointed out the important future to the workman who became a scientific man. The classes first opened at the institute were in physics, chemistry, and physiology; but the curriculum soon extended, and an important novel feature in popular education was introduced by Mr. Williams in what were so well known in the town as the 'Institute Penny Lectures.' The first of the series was delivered in the early part of 1856, and attracted large audiences. The first bench was occupied by factory boys immediately the doors opened, and, as intended, many who had their interest in science aroused for the first time were led to undertake the more serious and systematic courses provided at the institute. The idea of penny lectures led, subsequently, to the establishment of penny classes and penny readings, and did much in the direction of popular education."

Mr. Williams was an active citizen in Birmingham, and forward in every scheme for improvement and enlightenment. He was earnest in promoting the purchase of Asten Hall; wrote articles in the Journal urging a more liberal policy on the part of the Town Council, especially in measures for the improvement of the public health; was a leader in discussions concerning education, and advocated the introduction of object lessons and practical illustrations in teaching. He began his career as an author in Birmingham; contributed frequently to the Birmingham Journal; published a pamphlet on The Intellectual Destiny of the Workingman, in which he advocated manual occupations; contributed to the Chemical Society a paper describing An Apparatus for Collecting Gases over Water or Mercury; and, having made

a pedestrian tour through Norway, published his book Through Norway with a Knapsack.

While living here he became unwittingly connected with the Orsini plot for assassinating Louis Napoleon with bombs, which resulted in the destructive attempt of January 14, 1858. He was introduced to Orsini, whom he describes as "a highly educated, refined, and courteous Italian gentleman," in the fall of 1857, and having lived in Italy and witnessed the abuses of the despotisms with which the country was then saddled, "heartily sympathized with his patriotic yearnings for the liberation of his country." Orsini represented to him that the patriots were preparing for a great effort to drive out the foreign intruders, both Austrian and French, but that the watch upon them was so close that they could not introduce or hold ordinary arms. He had therefore invented a new form of stellar gas burner which could easily be converted into a bomb and used as a hand grenade. The gas-burner shells were, however, too small for a charge of ordinary gunpowder to produce effective explosion. Mr. Williams therefore suggested fulminate of mercury in lieu of the powder, and taught Orsini and Pieri how to make it themselves. They also learned how to make fulminate of silver and some other detonating compounds. Orsini, in his final confession, said that the English chemist (Mr. Williams) who taught him how to make the fulminate had no knowledge of its intended purpose. This assurance was accepted by Napoleon and the French police, who gave Mr. Williams no further trouble than that of a few days' secret watching of his movements in Birmingham, which was so delicately conducted that he only discovered it accidentally. Mr. Williams's sympathies with the Continental peoples who were oppressed by foreign despotisms were very strong, and he sometimes expressed them vehemently in his lectures, when he would denounce the Hapsburgs and hold up the Swiss as a pattern people.

Mr. Williams devoted considerable attention, toward the last of his residence at Birmingham, to the chemistry and manufacture of paraffin oil, for which he had patented a process of distillation from shale. Having been appointed manager of the Leeswood Oil Company, whose works were at Caergwile, near Wrexham, Wales, he left Birmingham in 1863, carrying with him a testimonial presented to him by students and friends of the institute. The oil-distilling process was worked with complete success, but without profit; for the product of the newly discovered oil wells of Pennsylvania came into the market at the time and destroyed the sales. Mr. G. Combe Williams writes that "during this part of his career his foresight and influence over the working class, for whose social and intellectual advancement he had devoted so much time and energy, were clearly demonstrated, for

while strikes and labor riots were going on in the surrounding works, his men worked on, having heard the facts of the case from him, and while the other oil-masters were almost without workmen during the agricultural harvest season, his personal influence was enough to keep his men at their work."

After the oil-distilling enterprise had failed, Mr. Williams went to Sheffield as chemist to the Atlas Iron Works. He conducted investigations on the manufacture of iron and steel, the effects of impurities in the same, etc., the accounts of which are fully reported in his book on the Manufacture of Iron and Steel. At Sheffield he wrote and published his book on the Fuel of the Sun, in which he assumed the existence of a universal atmosphere, upon the amount of which the planets can condense about their surfaces the densities of the planetary atmospheres depend. His speculations have not been adopted by astronomers; but the book is said to have received some curious criticisms, and contradictory—from the mathematicians, who said that "the mathematical part of the theory was correct, but there must be something wrong with the chemistry"; and from the chemists, who said that "the chemistry was all right, but there must be something wrong with the mathematics."

In 1870 Mr. Williams moved to London, where he engaged in lecturing at schools. In 1876 he gave what he called an object lesson in geography, when he took his pupils through Norway. An account of this journey is given in his book Through Norway with Ladies. He afterward gave up teaching at schools and devoted his time chiefly to scientific writing, contributing Science Notes to the Gentleman's Magazine, and papers and paragraphs to Science Gossip, Knowledge, Iron, and other periodicals. The more valuable series of these articles were collected and published in the Chemistry of Cooking (published in The Popular Science Monthly and by D. Appleton & Co.); Science in Short Chapters; A Simple Treatise on Heat; the History of the Manufacture of Iron and Steel; the Philosophy of Clothing, and Shorthand for Everybody. His uncle and adoptive father, Zachariah Watkins, by whom he had been helped in youth, to whom he dedicated The Fuel of the Sun, and with whom he dined every Saturday for twenty years, dying in 1889, left him an income that assured a comfortable support, and, as he wrote to Dr. Taylor, editor of Hardwicke's Science Gossip, he was able to begin his life work at the age of sixty-nine. This life work was A Vindication of Phrenology, on which he had been engaged, collecting material, writing, and revising, for fifty years. It was left fairly completed, and is to be published by a London house.

CORRESPONDENCE.

"WEISMANN'S CONCESSIONS."

Editor Popular Science Monthly:

DEAR SIR: In your issue of this month is an article by Prof. Lester F. Ward entitled Weismann's Concessions. In this Prof. Ward endeavors to show that Prof. Weismann has virtually acknowledged his own hypothesis on the inheritance of acquired characters to be untenable. But Prof. Ward's reasoning is vitiated by a thread of error that runs through the whole article, viz., the assumption that, in showing that Weismann concedes modification of the germ-plasm by agencies outside itself, with consequent variety in inheritance, he has shown that Weismann concedes the "inheritance of acquired characters" in the sense in which this expression is used by Weismann, Romanes, Lankester, and most other biologists of note. By the expression "inheritance of acquired characters," as used by Weismann and Romanes, is meant the acquirement *de novo* of characters by the somatoplasm of an individual (not characters that the somatoplasm has acquired in consequence of a modification of the germ-plasm) which, in some way, so modify that individual's germ-plasm that its descendants inherit the characters that it originally acquired. This is obviously very different from a modification of the germ-plasm by agencies external to it, that causes the development of new characters in the individuals developed from this germ-plasm and in their descendants. This last is *not* inconsistent with Weismann's theory of the continuity of the germ-plasm, while the "inheritance of acquired characters" (in the sense used by Weismann) is. Prof. Ward also speaks of the Lamarckian law as if he thought what is generally meant by "Lamarckianism" was different from "inheritance of acquired characters" (in Weismann's sense). He makes another obvious mistake where he criticises Weismann's statement on the inheritance of syphilis, and, if my memory serves me, he makes a great deal more out of his quotation from Romanes than Prof. Romanes ever meant, or the context of the words quoted justifies.

Weismann, while one of the clearest reasoners among biologists, is at times a little hard to understand on account of his style, and I think if Prof. Ward will reread his works he will see that he has not done Prof. Weismann justice.

I do not mean to pose as a supporter of all Weismann's views, but he seems to me to have a clearer conception of the problem of inheritance of acquired characters and of the nature of the proof necessary to solve it than almost any other man. At the same time there is hardly an author who is more misquoted and misrepresented—he is one of Darwin's chief rivals in this respect.

Yours very truly, F. R. WELSH.

328 CHESTNUT STREET, PHILADELPHIA,
June 9, 1894.

EDITOR'S TABLE.

MAN AND WOMAN.

WHEN men and women come to saying ungracious things of one another in a kind of hostile rivalry, the situation is not pleasant, and bodes no good to the coming generation. The evil may be a limited one, yet it is, as far as it exists, a real one, and is already embittering and unsettling a good many lives. Well would it be, therefore, if some one could come forward with an eirenicon that would still the unnatural jarring which is a decided feature of to-day's civilization.

It is the women to-day who are in the main on the aggressive. In fiction and essay they are employing their new-found intellectual powers in demonstrating how poor a creature is man. According to some, it would appear as if man had been the great imposture of the ages, and that a certain instinct of preservation had led him to deny culture to woman, lest he should be found out, and the bubble of his reputation eternally collapse. One recent writer, who, however, assumes a man's name, has it that if Nature had not implanted a trou-

blesome amount of affection in woman's composition, she could by her greater force of will and character drive man into a corner of the universe, just as the inferior races of the past have been driven before the superior ones—only more so, the disparity being greater.

This is not wholesome. If men have abused their power in the past, it is only what holders of power, who were also fallible mortals, might have been expected to do; and if women were wise, the lesson they would learn, now that they are more and more being placed in the way of acquiring power themselves, would be, if possible, not to abuse it so much as men in their day have done. There is little to be gained by turning the shafts of feminine wit against men, nor will the feminine character be improved by much indulgence in the practice. Better far will be a serious effort to rise to the level of their new opportunities and responsibilities. A man may be a great scholar and a great fool, and so, we venture to say, may a woman. It is a much easier thing to stimulate the intellect than to strengthen and enrich the moral nature; and it does not follow that, because women now have access to most colleges and universities, they are going at once to show a higher type of character. It is not impossible even that a reliance on those methods of culture which have been devised for men may tend to impair in a greater or less degree those finer intuitions which are claimed as the glory of the female sex, and in which we are quite prepared to declare our own firm belief. The intellectual differences between the sexes may be less than has hitherto been supposed; but there are differences nevertheless, and it is the manifest interest of the race that these should be developed and made prominent, rather than weakened and obscured. So greatly have the claims of women been advanced within the last half generation that it seems almost like offering an indignity to her present state to quote the lines of Tennyson so greatly admired in their day:

> "For woman is not undeveloped man,
> But diverse; could we make her as the man,
> Sweet love were slain."

Still, perhaps, there is wisdom in the words, and, if so, it might be well to suggest a caution lest, in the eager assertion on her part of equality in all points with man—not to say of superiority to him—something of inestimable value be, if not lost, allowed to fall into comparative disuse, with more or less of resulting injury.

If the human race is to endure, and if civilization is to advance, the relations between the sexes must not permanently be relations of rivalry. Men and women were not made to struggle with one another for the advantages of life, but mutually to aid one another in reaping those advantages. That "sweet love" of which the poet speaks is given as the reward of right relations between man and woman; and, where other guidance is lacking, we may profitably ask whether any given line of conduct tends to the gaining or the sacrificing of that reward. If to the former, then it may safely be said to be right conduct; if to the latter, wrong. What it is clear that man has to do in these later days is to frame to himself a higher and completer ideal of manhood than he has hitherto, on the whole, entertained, and try to live up to it. The awakened womanhood of the age—when allowance has been made for all that is hysterical and morbid and heartless in contemporary feminine utterances—summons him most clearly and distinctly to walk henceforth on higher levels in the strength of a nobler self-control. Then he has to recognize in the fullest sense, without a particle of reservation, that he has in woman not a weaker shadow of himself, not a reflection of his glory nor a minister to his pleasures, but a divinely bestowed helpmeet, to whom special powers and fac-

ulties have been imparted for the interpretation of truth and the beautifying of life. The ancient Germans, Tacitus tells us, used to recognize a certain divine power of intuition in their women, and if they did it was probably not without cause. The phenomenon is not an extinct one in our own day, and we venture to say that its frequency will wax or wane according to the respect paid not by man only, but by woman herself, to all in her nature that is most distinctive of womanhood. It is far from certain that woman always recognizes what her own best gifts are; and there is, in our opinion, a specific danger lest, in her new-born zeal for a masculine equipment of knowledge, she relegate to an inferior place that native truth of perception which is of more importance, we may almost say, than all formal knowledge.

The new times call for new virtues; and not too soon has man been awakened—or rather is he being awakened, for the process is far from complete—from what, with acknowledgments to Kant, we may call his "dogmatic slumbers." The Sphinx is at our gate again with its everlasting riddles, and woe betide us if we do not solve them! For this will be needed the combined wit and wisdom of the best men and women of the time, and by the best we mean not those who pride themselves on the most encyclopedic knowledge, but those rather who with sufficient knowledge to understand the world around them can, by the exercise of the deepest human feeling, place themselves at the heart of the social situation, and so give us a clew to "the master knot of human fate." The great remedy for vain rivalry and stupid competition of wits is to join hands and hearts in useful work—in work for that universal humanity which, though not a fit object of worship, is at least an inspiring object of devotion.

THE MEANING OF DYNAMITE.

Mr. Auberon Herbert, in the May number of the Contemporary Review, discusses in a very philosophical spirit the dynamite outrages that have been occurring of late in Europe, and particularly in France. The dynamiter, he says in effect, is simply a man who, finding that governments are founded on force, and that in many cases they have no higher warrant than their irresistible power for the actions they perform, determines to get even with them by the only means within his reach. He has not learned "the trick of the majority," and so can not proceed openly to impose his will upon others. He can not uniform a policeman and arm him with club and pistol, so he arms himself with a dangerous and easily secreted explosive, and places it with lighted fuse where, from his point of view, it will do most good. At first sight it might seem that Mr. Herbert is maintaining an outrageous paradox; but it is not so: he is entirely serious, and, in our opinion, he fully establishes his thesis that over-government leads to dynamite. He cites France as a conspicuous example of an over-governed country, and cites a multitude of facts which show how little respect, in spite of the republican form of its institutions, is paid to individual liberty, how horribly the omnipresent power of government intrudes into the daily life of the citizens. Mr. Herbert goes on to say:

"What I have said of France might be said, with the necessary difference, of other European countries—each country being vexed and harassed by its bureaucrats, and each being affected in its own way according to the genius of the people. But in each country the general effect is the same. Almost every European government is a legalized manufactory of dynamiters. Vexation piled upon vexation, restriction upon restriction, burden upon burden—the dynamiter is slowly hammered out every-

where upon the official anvil. The more patient submit, but the stronger and more rebellious characters are maddened, and any weapon is considered right as the weapon of the weaker against the stronger."

England, the writer admits, is in a different position. "We have inherited," he says, "splendid traditions of voluntaryism, which hardly any other nation has inherited; and it is to voluntaryism, the inspiring genius of the English character, that we must look in the future, as we did in the past, for escape from all difficulties. If we can not by reason, by influence, by example, by strenuous effort, and by personal sacrifice, mend the bad places of civilization, we certainly can not do it by force." At the same time England has entered, he considers, on the dangerous path of paternal and protective legislation. As yet she has only soiled her ankles—so he expresses it—where other nations have waded deep, and it is not yet too late "to step back from the mire and slough which lie in front of her." The question is, Will she? Under the guise of socialism and humanitarianism, the spirit of compulsion is in the air. The well-meaning everywhere are longing to see whether they are not, or can not command, a majority in order that they may begin to wield that compulsive power which it is one of the strange delusions of the modern world that majorities have a right to exercise in everything. Yet if one were to propose to put any one of these well-meaning persons under the absolute control of another well-meaning person, who should prescribe for him his comings and goings, decide for him what causes he should support, how much money he should give in charity and for what particular objects, how much wealth he should accumulate and at what point the fruits of his industry should pass over to the state, we greatly fear that well-meaning person number one would make strong objections. True, he wants, with the aid of those who agree with him in opinion, to settle these points for others; but he has never seriously considered what it would be like to part with his own liberty. Ordinary human beings require something more than an assurance of another person's good intentions before they are willing to make a surrender to him of any large measure of their freedom of action; and we imagine that many of those who to-day advocate an indefinite increase in the power of the state do so under a fond impression that *their* particular views and schemes, humanitarian or other, will always prevail. They, with the help of others like-minded, want to govern the world for its good. Well, what tyranny ever professed less? Good intentions are excellent things to have, but when they make alliance with the policeman's truncheon they become committed to many devious lines of policy, and quickly assume all the odious characteristics of tyranny.

But does not the present unchecked action of *laissez-faire*, it may be asked, threaten danger to society? Society as an organism, we answer, will always be subject more or less to disturbances; but the important thing is to see that we do not interfere with the compensating actions which, like organisms in general when thrown out of equilibrium, it has the power to set up. Action and reaction in the social world, as elsewhere, are equal and opposite; and given the fact that man's instinct is to pursue happiness, and the further fact that the happiness of each individual is largely dependent on the dispositions of others, the actions and reactions taking place in a society not strangled by government control would steadily tend toward an increase of the general welfare. Public opinion is, in all free communities, a powerful agent of reform; but it would be still more powerful if it did not so often seek to embody itself in law. We have yet to be convinced that the world has suffered injury by any application of *laissez-faire*. Under that

régime things will not always be done rightly, but neither would they always be done rightly under any system of tyranny, socialistic or other, that could be invented. *Laissez-faire* was probably never carried further in the history of the world than in the early history of the several colonial communities which afterward combined to form these United States; and the principles of paternalism and protection in government were probably never carried further than in the management during the same period of the French colonies to the north and east of us. And what was the result in either case? The neglected colonies of England, with their very loose system of local government, grew strong and vigorous and wealthy, while the over-protected colonies of France seemed smitten with industrial and commercial paralysis. In war the latter were for the most part efficient and formidable, because then they acted in complete submission to leaders accustomed to command; but in peace they languished and withered. The English colonies, the New England ones in particular, might be compared to vigorous youngsters full of animal spirits, and meeting with many a disaster through their recklessness and impatience of control. The French ones, on the other hand, resembled puny and exacting nurslings always crying out for maternal help and succor. *Laissez-faire* has its drawbacks, but it means, on the whole, wealth, vigor, resource, and capacity for recuperation. It does not mean dynamite; the latter, as Mr. Auberon Herbert has well shown, being the natural concomitant of over-government.

LITERARY NOTICES.

SOCIAL EVOLUTION. By BENJAMIN KIDD. New York: Macmillan & Co. Pp. 348. Price, $2.50.

THIS is a work marked to a more than usual extent by independence and originality of thought, and one which will set a great many persons thinking on new lines. After a careful perusal of it, however, we are led to doubt whether the author's own conclusions are very well matured. He has caught sight, as he believes, of some important principles hitherto unrecognized, or but imperfectly recognized, in the field of social philosophy, and with the eagerness natural to a discoverer he has communicated them to the world without waiting to determine their exact scope and application. The result is more or less of incoherence and not a little of apparent self-contradiction in what nevertheless is from first to last an interesting and impressive dissertation upon a most important subject.

Mr. Kidd's first chapter deals with The Outlook. He believes the world to be on the eve of great changes. "Social forces," he says, "new, strange, and altogether immeasurable, have been released among us. . . . The old bonds of society have been loosened; old forces are becoming extinct. . . . The air is full of new battle cries, of the sound of the gathering and marshaling of new forces and the reorganization of old ones." What is the meaning of it all? Science herself, Mr. Kidd tells us, "has obviously no clear perception of the nature of the social evolution we are undergoing." Well, then, who has? If Mr. Kidd, who claims above all things to be pursuing rigorously scientific methods, why should he deny science any share in his work? It seems to us that if Mr. Kidd, as a scientific man, can forecast the future of society, it would be only using words in their usual acceptation to say that "science" has, in a certain measure, solved the problem. Of course, if Mr. Kidd claimed to have a revelation from heaven, that would be a different thing; he claims, on the contrary, to be an out-and-out evolutionist, a Darwinian of the Darwinians, and a Weismannian to boot. He tells us a little further on that "the definition of the laws which have shaped, and are still shaping, the course of progress in human society is the work of Science, no less than it has been her work to discover the laws which have controlled the course of evolution throughout life in all the lower stages." So we have always thought; and we have felt sure that Science, as soon as she gathered and sifted a sufficiency of facts, would dem-

onstrate to the world that the one was her sphere quite as much as the other. It should be needless to add that such has been the conviction of all who have had any tincture of social philosophy ever since the early years of the present century, not to go further back.

But without entering too much into criticism we must endeavor briefly to set forth a few of Mr. Kidd's leading ideas. He finds that science is strangely at a loss respecting the meaning and function of systems of religion in man's life and history. Well, of course science has much to learn, else it would not be science, but theology, or some such privileged branch of human knowledge; and, having much to learn, she is as willing to learn from Mr. Kidd as from any one else. Mr. Kidd has reflected deeply on this question of the significance of religious systems, and he finds that their main, if not only, function is to supply the lack of a rational sanction for the conditions of progress. His third chapter has for title There is no Rational Sanction for the Conditions of Progress, by which he means that, when men exercise the self-control or exhibit that regard for the interests of others on which social progress depends, they act foolishly from the individual point of view—their conduct has no rational sanction. Religion, however, steps in and supplies an "ultra-rational" sanction, and the maintenance of that sanction is of such importance to the life of societies that Religion pushes Reason aside and condemns it to a position of inferiority in order that her work may not be interfered with. "There never can be," observes our author, "such a thing as a rational religion"; seeing that "the essential element in all religious beliefs must apparently be the ultra-rational sanction which they provide for social conduct." Or, as he puts it, with more precision, "a rational religion is a scientific impossibility, representing from the nature of the case a contradiction in terms." Different civilizations are simply the varying modes or systems of human life that have formed around different types of religious belief. When a religion dies the civilization dies also. It may linger for a while by virtue of the inertia of established forms, but the soul has gone out of it, and it soon falls into decay. Intellect the author speaks of as a "disintegrating principle" tearing asunder the fabrics which instinct has woven; but if we ask what useful function it performs, we do not get from the work before us—which, however, doubtless owes its origin more or less to intellect—any very satisfactory answer. It has had something to do, he seems to admit, with our progress in the arts and sciences; but its services are not acknowledged in any very liberal fashion; nor are we furnished with any indication of the limits which the author thinks should be set to the exercise of the intellect.

The author is emphatic in his assertion that social progress can only be made through the free action of natural selection, and he states that "the avowed aim of socialism is to suspend that personal rivalry and competition of life which not only is now, but has been from the beginning of life, the fundamental impetus behind all progress." One would suppose from this that he had no faith in socialism; and yet, in his chapter on Modern Socialism and elsewhere, he seems to anticipate great and beneficial results from a vast extension of socialistic legislation. The fact is that it is very difficult to fix with any certainty the author's position on many of the questions he discusses. The best chapter in the book, to our mind, is the one entitled Human Evolution not Primarily Intellectual, in which he points out, we think with truth, that "certain qualities, not in themselves intellectual, but which contribute to social efficiency, are apparently of greater importance" than purely intellectual ones in promoting civilization and strengthening the basis of national life. In a word, the race, on the whole, is not to the smart, but to the good, to those whose social instincts are strongest and social habits the best. The whole book is worth reading, but it should be read in a critical spirit, otherwise it will teach quite as much of error as of truth.

GENERAL SCOTT. Great Commanders Series. By General MARCUS J. WRIGHT. New York: D. Appleton & Co. Pp. 349. Price, $1.50.

BORN a few years after the close of the Revolution, and living through the period of the civil war, Winfield Scott was contemporary with nearly all the important military

events in our country's history. He was a Virginian by birth, of Scotch ancestry. That the belligerent faculty which was afterward so valuable to his country was early developed, is shown in an anecdote of young Scott punishing a bully who was abusing the youth's Quaker teacher. Young Scott entered the legal profession, but in 1807 one of the incidents that foreshadowed the War of 1812 caused him to join a troop of militia cavalry. When a more serious incident occurred a year or two later, Scott received a commission as captain. When war was actually declared, he was made a lieutenant colonel, although being then only twenty-five years of age. General Wright gives a detailed account of the operations of this war, in which Scott won an enviable record for gallantry and a promotion to a generalship. General Scott had gained some experience in Indian fighting during the war with England, and saw more of the same kind of service in the troubles with the Sacs and Foxes, the Seminoles, and the Cherokees. He was sent to South Carolina at the nullification time to act in case of an outbreak. The chief part of General Scott's reputation was made in the round of successes constituting the war with Mexico. The siege and capture of Vera Cruz, the battle of Cerro Gordo, and the operations around the capital city ending in Scott's triumphal entry, are described with gratifying fullness. The rest of the volume is occupied with minor events, including his nominations for the presidency, his honors, travels, administration of various military affairs, his retirement from the chief command of the army at the beginning of the civil war, etc. The various controversies in which a strong will and somewhat choleric disposition involved him are not concealed, and a wealth of anecdote illustrates all sides of his character. A frontispiece, portrait, and several maps illustrate the chronicle.

APHORISMS FROM THE WRITINGS OF HERBERT SPENCER. Selected and arranged by JULIA RAYMOND GINGELL. With Portrait. New York: D. Appleton & Co. Pp. 166. Price, $1.

"How to live? that is the essential question for us Not how to live in the mere material sense only, but in the widest sense. The general problem which comprehends every special problem is the right ruling of conduct in all directions, under all circumstances." (Education, chap. i.)

This is the first selection in the volume. For many centuries man has been working out the solution of the problem to which it refers, and has made the best progress within the past generation. Just as his empirical knowledge of bodily hygiene has been greatly extended by the discovery of micro-organisms, so has his understanding of right conduct been broadened and systematized by the doctrine of evolution. Miss Gingell has made her book of extracts bear largely upon the management of life. Mr. Spencer being the chief exponent of evolution, the principles of conduct found in his writings are coordinated and unified by that great luminous truth which both lights up the past and enables us to peer into the future. This collection of aphorisms consists of brief, pithy sentences and paragraphs culled from the whole range of Mr. Spencer's writings and grouped under such headings as education, evolution, politics, justice, sympathy, happiness, etc. It has never been any part of Mr. Spencer's plan to prepare material that could be used in this way. The units of his writings are the chapters, and a passage taken out from its context is apt to give a misleading impression when standing alone. Yet Miss Gingell has carried out her undertaking with much tact, and the volume furnishes a sample of Spencer's quality from which readers may decide whether or not they desire to read any of his connected works.

MATERIALS FOR THE STUDY OF VARIATION, TREATED WITH ESPECIAL REGARD TO DISCONTINUITY IN THE ORIGIN OF SPECIES. By W. BATESON, M. A. Cambridge. London: Macmillan & Co., 1894. Pp. 598. Price, $6.50.

THE first portion of the above title is printed on the back of the book, and, considered under this title alone, Mr. Bateson has made a most valuable contribution to the study of variation. He has classified the phenomena, so to speak, and given some new and convenient terms to express the kinds of variation. The phenomenon of the repetition of parts he terms *merism*; numerical and geometrical changes are called *meristic*

changes; changes in the constitution or substance he calls substantive variation, and these various changes may be continuous or discontinuous. The word *homœosis* is substituted for metamorphy—this term being applied to cases such as the eye of a crustacean developing into an antenna, or the petal of a flower into a stamen, etc. He has systematized the sports, freaks, and redundancies of Nature, and has done an amazing amount of hard work in a field to which few have been hitherto attracted. He has also emphasized in the most telling way one of the most important factors in the doctrine of natural selection—namely, variation. As to the author's conception that the discontinuity of species is at all sustained by this evidence, we can not agree. His introductory pages—and there are many of them—are as laborious reading as similar portions of Buckle's History of Civilization. Man's power of apprehension, nowadays, has so far advanced that there is no longer any necessity for iterating and reiterating self-evident propositions.

Demonstrating, as he does, sudden and spontaneous modifications in animals, he assumes, without sufficient proof, that the divergent characters of many species have originated in this way. He asks, May not specific differentiation have resulted from individual variation? The answer to this would be that if these extraordinary jumps are ever perpetuated for a time even, like the double operculum in *Buccinum undatum*, for example, which he cites, the wildest species-maker has never dreamed of making a separate species of such freaks. They are hardly accounted varieties.

The author says that Lamarck's view points out that living things can in some measure adapt themselves, both structurally and physiologically, to new circumstances, and that in certain cases the adaptability is present in a high degree. He also formulates Darwin's theory as showing the survival of those adapted to the environment. "According to both theories, specific diversity of form is consequent upon diversity of environment, and diversity of environment is thus the ultimate diversity of specific form. Here, then, we meet the difficulty that diverse environments often shade into each other insensibly and form a continuous series, whereas the specific forms of life which are subject to them on the whole form a discontinuous series." We should question this latter statement. We have, for example, the two great provinces of land and water; we have also marked and emphatic divergencies in these larger provinces; the deep, moist cañon in an arid plain, the sharp line between light and darkness with their appropriate forms salt and fresh water, with the intermediate brackish water and the paucity of brackish water forms, and these pointing to their evident origin and subsequent adaptation; and rivers flowing through limy and granitic regions, with examples of mud lakes, sand lakes, and salt lakes. Indeed, the zones of demarcation are often so narrow that the varieties due to these selective features struggle almost hopelessly to keep up an existence.

Mr. Bateson seems to think that physical environment is the only selective action in the struggle for existence; but to those who have studied Darwin there are many other features to be taken into account, of which no mention is made. Ignoring the theory of natural selection, but recognizing the prime importance of variation as the essential phenomenon of evolution, he says, "Variation, in fact, is evolution." He overlooks the importance of all other factors upon which the theory of natural selection rests—inheritance, without which the theory would fall; the numerical proportion of individuals remaining the same, without which fact it could not be shown that an infinitely greater number of individuals perish than survive.

These equally important factors are laid aside, and he emphasizes the statement that variation, in fact, is evolution. This is as logical as if one should say evolution could not exist without life, life could not exist without oxygen (omitting certain forms of bacilli), and hence oxygen is evolution.

He repudiates the law of Von Baer, and says "it has been established almost entirely by inference, and it has been demonstrated in scarcely a single instance." Mr. Bateson can not understand why one species of moth differs a little in pattern from another species. He can not understand the utility of small differences which distinguish species. In his regard for species he should be reminded of the large number of species formerly considered good which have merged

into others as varieties or subvarieties. Many of these species, furthermore, were made by keen observers who devoted their whole time to making them, and were adepts at the work, and yet in the light of the studies of Baird, Coues, Allen, Ridgway, Brewer, and others these specific distinctions have been broken down, and many of these formerly well-recognized species are now known as geographical varieties.

His work is filled with a large number of cases of deformation, atrophy, hypertrophy, duplication of parts, etc. Varietal groups are one thing; double-headed monsters, supernumerary digits, etc., are quite another thing, and no one has ever been tempted to look in that direction for new species; indeed, the collector has rarely been inclined to save such freaks, and so Mr. Bateson's book is all the more remarkable for presenting such a large array of material.

After turning the last page we say to ourselves, If such profound structural divergencies can arise, how elastic the organism must be, and how infinite must be the number of minor variations of strength, endurance, color, proclivities, etc., which is all the material the Darwinian demands to sustain the doctrine of natural selection as an all-sufficient cause!

TOTAL ECLIPSES OF THE SUN. By MABEL LOOMIS TODD. Columbian Knowledge Series. Number 1. Edited by Prof. DAVID P. TODD. Boston: Roberts Brothers Pp. 244. Price, $1.

THE opening volume of the Columbian Knowledge Series is a remarkably picturesque book. Dealing with those impressive moments, of infrequent occurrence in any one locality, when the face of Nature seems transformed, it appeals strongly to popular interest. Moreover, the fact that these occasions afford rare and precious opportunities for valuable scientific observations makes the subject doubly attractive to all intelligent minds. Mrs. Todd has made excellent use of her opportunities. With rare powers of description she tells how eclipses occur, describes their phenomena, and relates the incidents of various expeditions for observation. A historical sketch of eclipses from the remote past down to 1893 is given. Considerable is told about instruments and photographic appliances used in observing eclipses. A notably interesting feature is a list of future total eclipses of the sun, with a chart showing where they will be visible, and there is a similar list and chart of past eclipses since 1842. The proofs of the book have passed under the scrutiny of Prof. C. A. Young as well as that of Prof. Todd, so that readers need have no fears of inaccuracies. The volume is copiously illustrated and has an index.

POPULAR LECTURES AND ADDRESSES. Vol. II. GEOLOGY AND GENERAL PHYSICS. By Sir WILLIAM THOMSON (Baron KELVIN). London and New York: Macmillan & Co. Pp. 599.

THE volume of Lord Kelvin's Popular Lectures now issued completes the set of three volumes. Among the subjects discussed in the geological papers and addresses are geological time, geological dynamics and climate, the doctrine of uniformity, the internal condition of the earth, and polar ice-caps. In one of the addresses delivered before the British Association, Lord Kelvin has discussed the sources of available energy in Nature, designating them briefly as tides, food, fuel, wind, and rain, all but the first of which are derived from the sun. There are also addresses, more general in character, delivered at the opening of the Bangor laboratories, at the unveiling of a statue of Joule, and at three anniversary meetings of the Royal Society.

PUBLIC LIBRARIES IN AMERICA. By WILLIAM I. FLETCHER. Columbian Knowledge Series. Boston: Roberts Brothers, 1894. Pp. 169. Illustrated. Price, $1.

EVERY essential fact regarding the public libraries of America is here told in brief compass by the eminent librarian of Amherst College. The claims of the public library as a means of refined entertainment, as a gainful partner to the school, the workshop, and the studio, as here set forth, are certainly weighty enough for national conviction. To the public-spirited men and women who either wish to improve a library already established, or who desire to found one, Mr. Fletcher's chapters are indispensable. He concisely passes in review the selection of books, their fit housing, and the management of a library, this last task now much lightened for trustees and

committees by the library schools at Albany, Brooklyn, and at Amherst, where Mr. Fletcher himself presides. In discussing library foundations our author commends those created by gift, yet he observes that an institution is nearer the popular heart when spontaneously built up and controlled by the community it serves. Basing a forecast upon the recent rapid growth of public libraries, not only in number but in usefulness, Mr. Fletcher expects in the future a still further expansion for them. In this connection a list published last April by the Public Library of Paterson, N. J., is significant. This list presents works on astronomy, selected by Prof. C. A. Young, of Princeton, who appends brief notes to the principal titles. Lists such as this, ampler in range and fuller in annotation, would double the value of every public library incorporating them in its catalogue. At one pole of education are the teachers of mark who can appraise the working literature of instruction, at the other pole are unnumbered inquirers at library desks who know not what to choose; to bring together the trustworthy guides and the baffled wanderers would mark a new era in popular enlightenment, would break down another wall dividing those who need from those who have and are willing to give.

PAIN, PLEASURE, AND ÆSTHETICS: AN ESSAY CONCERNING THE PSYCHOLOGY OF PAIN AND PLEASURE. By HENRY RUTGERS MARSHALL, M. A. London and New York: Macmillan & Co. Pp. xxi+364. Price, $3.

THERE is a certain smoothness, sobriety, and clearness about this work of Mr. Marshall that appeals with peculiar emphasis alike to the artist and the scientist. At once the æsthetic taste and the spirit of scientific inquiry are in a large measure satisfied. The author, indeed, is open to admit that this is by no means a subordinate aim in the volume under consideration. As is plainly manifest, he comes as a peace-maker between the artistic aspirant who misconceives or deems the teachings of science antagonistic to his favorite pursuit, and the scientific investigator who suspects artistic predilections as either inimical to or in the way of science. Nothing that ministers to the melioration of that harmonious understanding which ought to have obtained where it was lacking, has been kept out of sight, and happily for two great departments of learning, a literary link has been added to the chain of progress. While the work, in its seven tersely written chapters, treats mainly of psychological problems, the undertone, apart from the author's prominent design, is essentially æsthetic in its tendencies, a fact that forms almost imperceptibly a mental meeting ground for scientist and artist. Chiefly, the latter is impelled by an inner and perpetual voice which expressly commands him to act. But he is primarily a listener, an interpreter of high and noble promptings. As such, he can have naught against the "physical discoverer," to whom, as Tyndall has admirably put it, "imagination becomes the mightiest instrument." In turn, the scientist is indebted beyond measure to the genius of art, and gains from it in regions decidedly æsthetic many of the joys of life, which indirectly contribute and betimes directly suggest his boldest flights and most clearly conceived problems.

The book abounds with interesting comparisons grouped within well-defined limitations. With a psychological classification of pleasure and pain, the reader is asked to contemplate the instincts and emotions, the field of æsthetics, the physical basis of pleasure and pain, and algedonic æsthetics. The work as a whole is a general as well as technical survey of comparatively new ground.

THE LAW OF PSYCHIC PHENOMENA. By THOMSON JAY HUDSON. Chicago: A. C. McClurg & Co. Pp. 409. Price, $1.50.

THOSE who are interested in the outlying parts of the field of psychology will welcome this book. It is a treatise on hypnotism, mental healing, spiritism, telepathy, clairvoyance, and allied subjects, by one who is convinced of the reality of such manifestations and seeks to explain them as caused by natural, though unfamiliar workings of the human mind. The "law" referred to in the title is also described as a working hypothesis which is expected to guide further study of psychic phenomena. It is stated in three propositions: First, "Man has, or appears to have, two minds, each endowed with separate and distinct attributes and powers; each capable, under certain conditions, of independent action. . . . The second proposition is,

that the subjective mind is constantly amenable to control by suggestion. The third, or subsidiary, proposition is, that the subjective mind is incapable of inductive reasoning." The author proceeds to discuss the various classes of psychic phenomena on the basis of these propositions, especial attention being given to "psycho-therapeutics," or healing by suggestion. He analyzes carefully the results obtained by the prominent investigators of hypnotism, rejecting many of the inferences of certain too enthusiastic hypnotists. He denies that a hypnotic subject can be led into criminal acts by suggestion when the subject would not commit such acts independently. The common principle underlying the healing effect of the faith cure, mind cure, Christian science, etc., is sought for, and a new system of mental therapeutics is then set forth. The author accepts the phenomena of spiritism as realities, but denies that they are produced by the agency of the dead. In the closing chapters the physical manifestations and the spiritual philosophy of Christ are discussed. The book is temperate in tone, and its style is graceful and concise.

MINERVA. JAHRBUCH DER GELEHRTEN WELT (Minerva. Year-Book of the Learned World). Edited by Dr. R. KUKULA and K. TRÜBNER. Third Year: 1893–'94. Strasburg, Germany: Karl J. Trübner. Pp. 861.

THE compilers profess in this, the third year's issue of their work, to have endeavored to approach still nearer to their purpose, which is defined to be to furnish the most authentic and complete data possible concerning the scientific institutions of the whole world. The accounts of many institutions have been made more complete, and others which were wanting have been added. Of German institutions the more important archives have been revised and a number of libraries not before included; of Austrian, the archives and the university institutes; of French, the provincial libraries, for which last the special services of Ulysses Robert, inspector-general of French libraries and archives, are acknowledged. Other additional and fuller facts have been furnished concerning Scandinavian and Russian institutions by Prof. Lundell, of Upsala. Assistance has been given by Signor Chilovi, of the National Central Library in Florence; Prof. T. E. Holland, of Oxford; Prof. J. E. Sandys, of Cambridge; Prof. Gallie, of Utrecht; Prof. Nicholas Murray Butler, of New York; and others in Bucharest and Vienna. Dr. Reinold Rost, of the India Office, London, describes the institutions of India, and Dr. Vallers, of Cairo, the Arabian Academy of that place. The volume contains a list of the institutions arranged geographically; descriptions of technical and agricultural high schools, veterinary schools, academies of forestry, and other independent scientific institutions, libraries, and archives, arranged in alphabetical order; statistics of students attending the institutions; and a personal register. In the United States are described twenty-eight universities and colleges, two technical schools, two theological seminaries, twenty-seven libraries (not college libraries), nineteen independent observatories, four learned societies (in New York and Philadelphia), six museums, and the department institutions in Washington.

The *Report* for 1892, of the *Board of Control of the New York Agricultural Experiment Station* notices the improvements that were made in the property of the station, and carries with it, in the reports of the director and others, accounts of the researches that were carried on. These researches, which were also the subject of bulletins, concern the feeding of hens and chickens, black knot on the plum and cherry, spraying with fungicides, analyses of materials used in spraying and the influence of copper compounds in soils on vegetation, analysis of commercial fertilizers, the manufacture of cheese, and diseases of the bean. An address by Director Peter Collier on What is the New York Agricultural Experiment Station doing for the Farmer? is published in the report, and conveys much information concerning the general working of the station and its usefulness.

Dr. *Eduard Suess*, Professor of Geology at the University of Vienna, published a volume a few years ago on The Future of Gold, in which he tried to show that from geological indications we must expect in the future a scarcity of gold and an abundance of silver, and that the extension of the gold standard to all civilized states is impossible.

In 1892 he published a work on the *Future of Silver*, which, translated by Robert Stein into English, is now printed and circulated by the Finance-Committee of the United States Senate. In this essay the author reaches the conclusion that, assuming that the system of metallic coinage continues to exist, silver will become the standard metal of the earth, and that "the question is no longer whether silver will again become a full-value coinage metal over the whole earth, but what are to be the trials through which Europe is to reach that goal."

Charles Denison's Climates of the United States, in colors, already well known in its form in charts, has been revised and condensed in dimensions, and is now published in a convenient little volume by the W. T. Keener Company, Chicago. It gives in maps, with scales of colors graphically showing the intensity of the phenomena in the different regions, the average annual cloudiness, rainfall, temperature, and winds, the elevations of different regions, and the combined atmospheric humidities and seasonal isotherms and wind indications for each of the seasons throughout the whole United States, excepting Alaska.

Dr. *Adolf Brodbeck*, of Zurich, believes that in his little pamphlet, *Die Zehn Gebote der Jesuiten* (The Ten Commandments of the Jesuits), the truth about the Jesuits and their relation to Christendom is said for the first time. The authorities on which he relies are the classical writings of the order.

George H. Boehmer prefaces an interesting study of the *Prehistoric Naval Architecture of the North of Europe* (United States National Museum) with a brief notice of Greek and Roman boats, the constructions of the Germans, and such ancient boats as have been found in England. By far the largest part of the paper is devoted to Scandinavian boats, of which a considerable number have been found in the northern countries. This gives opportunity to describe the situations and positions of these boats, their surroundings, and the articles which were found with or near them, so that incidentally much information is conveyed concerning Scandinavian archæology in general.

Christ, the Patron of all Education, is the title of a sermon preached by the Rev. *Charles Frederick Hoffmann* before St. John's Guild of Hobart College, on the occasion of the commencement of that institution in 1893. It is published, by request of the guild and of members of the college faculty, by E. and J. B. Young & Co., New York. In company with it the same house publishes, also by request, an address delivered by Dr. Hoffmann on the occasion of the laying of the corner stone of St. Stephen's College, Annandale-on-the-Hudson. The subject is The Library of a Divine Child.

The composition of *The Study of the Biology of Ferns by the Collodion Method* was begun by *George F. Atkinson* after he had been successful in applying the method in his classes to the preparation of the very delicate tissues of ferns, and especially to the infiltration of prothallia without shrinkage. He started to prepare a simple laboratory guide, giving directions for preparing the various tissues, with a few illustrations, made chiefly from preparations put up by students in their regular work, together with some descriptive matter. Gradually other features were added, and the book grew to its present volume of 134 pages, constituting a fairly full technical manual. The first part is descriptive of the life cycle of ferns, their reproductive organs, parts, growth, and functions. The second part relates to methods of preparation and examination. The study is published by Macmillan & Co., New York, at the price of $2.

The *Eighteenth Annual Report of the Secretary of the Michigan State Board of Health* for 1889–'90, besides the regular matter of official routine in the first part, contains in a second part a number of papers, abstracts, and reports, among which are one on the Principal Meteorological Conditions in Michigan in 1889; one on the Time of Greatest Prevalence of each Disease, being a study of the causes of sickness in the State; and one on Dangerous Communicable Diseases in Michigan in 1889, relating to diphtheria, smallpox, measles, scarlet fever, typhoid fever, whooping-cough, pneumonia, dysentery, glandular hydrophobia, and lump-jaw. *Henry B. Baker*, Secretary, Lansing.

The Rev. *T. W. Webb's* very useful and convenient work on *Celestial Objects for Common Telescopes*—a fitting companion for Mr. Serviss's Astronomy with an Opera

Glass—has been revised and greatly enlarged for the fifth edition by the Rev. T. E. Espin, and is now published by Longmans, Green & Co. in two volumes. Preparatory to beginning his work on the new edition the author invited suggestions from amateurs, obtained advice from the Astronomical and Statistical Society of Toronto, and received assistance from special students of the sun, the moon, the planets, the comets, and meteorites. The original text has been left unaltered as far as possible, and the new matter added is placed in footnotes. The catalogue of Struve has been used as a basis. The objects have been arranged in the order of their right ascensions in the constellations.

The most important event mentioned in the *Report of the Harvard Astronomical Observatory* for 1893 is the completion of the new fireproof brick building, and the transfer to it of about 13,000 stellar photographs. The entire income of the Paine fund has become available for the use of the observatory. Photographing celestial objects under the Henry Draper memorial continues. The most important object taken is a new star in the constellation Norma, July 10th, which has a spectrum appearing identical with that of Nova Aurigæ. A higher meteorological station has been established in Peru than even Chachani. It is on the summit of the volcano El Misti, 19,200 feet above the sea. The latest publications of the *Annals of the Observatory* received by us are Vol. XIX, Part I, Researches on the Zodiacal Light and on a Photographic Determination of the Atmospheric Absorption; Vol. XXV, Comparison of Positions of the Stars between 49° 50′ and 55° 10′ North Declination, between 1870 and 1884, by W. A. Rogers; Vol. XXIX, Miscellaneous Researches made during the Years 1883–'93; Vol. XXX, Part III, Measurements of Cloud Heights and Velocities at Blue Hill Meteorological Observatory, by H. H. Clayton and S. P. Ferguson; Vol. XXXI, Part II, Investigations of the New England Meteorological Society for the year 1891; Vol. XL, Part II, Observations made at the Blue Hill Meteorological Observatory in the year 1892.

It is only by degrees and with difficulty that the study of natural science has been able to draw away from the domination of older subjects of instruction. The early guides in the experimental method unavoidably retained too much of the character of text-books. In *Laboratory Studies in Elementary Chemistry*, prepared by Prof. *Le Roy C. Cooley* (American Book Company, 50 cents), an especial effort has been made to secure purely experimental study, which is something more than verifying statements found in books. Directions for a hundred and fifty experiments are given, and the student is told the object of each, but not what he is expected to see. At the close the application to qualitative analysis of the facts and principles learned is pointed out.

The Problem of Mayflight is considered by *James Means* (W. B. Clarke & Co., Boston, publishers, 10 cents) from the point of view that the solution is to be sought in the principle of the soaring of birds. The author calls attention to the fact that the feat of safely sliding down a long and gentle incline upon an aëroplane has been performed by Otto Lilienthal, of Steglitz, Prussia, and adds that "in order to travel long distances in the air it is only necessary to improve the dirigibility of the aëroplane so that the angle of descent can be brought to a minimum." This can be done by making repeated experiments with very simple and inexpensive mechanical contrivances called soaring machines, these to be dropped from a height. Experiments with machines of this kind should be encouraged, with regattas and large prizes. With machines made automatic in their steering action, flights like Lilienthal's will be no more dangerous than football, quite as interesting, and far less barbarous.

A preliminary study of *The Derivation of the Pineal Eye* is published by William A. Locey, of Lake Forest, Ill., in the Anatomische Anzeiger, of Jena.

The *State Library Bulletin, Legislation*, comprises a classified summary of new legislation, with a subject index, which is prepared by entries on cards made as fast as proofs or advance copies of the session laws can be secured. This index is printed at the beginning of each year in order to inform legislators and other State officers what of special value in the subject under consideration in the publications of other States is available in the New York State library. The references in Bulletin No. 4, January, 1894,

cover the laws enacted in 1893 by thirty-nine States and one Territory. In most cases the laws are briefly summarized as well as cited, in order to present clearly and concisely material for comparative study of the most recent phases of State legislation on all subjects of general interest. (Published by the University of the State of New York, Albany. Price, 20 cents.)

In a paper on the *Prevention of Tuberculosis in Ontario*, read before the Ontario Medical Association, Dr. *E. Herbert Adams* advocates such measures of administration and education as will make sure the total destruction of the products of expectoration, and of the germs of the disease in every other form.

The *Journal of Social Science*, No. XXXI, January, 1894, includes more than half of the Saratoga papers of 1893. The one occupying the first place, and probably of widest general interest, is the tribute of Mr. Edward B. Merrill to the life and public service of George William Curtis. Other papers are the report of F. B. Sanborn on Socialism and Social Science; a review of recent progress in Medicine and Surgery, by Dr. Frederick Peterson; Compulsory Arbitration, by H. L. Wayland, D. D.; three papers in the Finance Department, relating to the silver question, bimetallism, and The Three Factors of Wealth; three papers in the Social Economy Department—two of them relating to Mutual Benefit Societies and the Sweating System; three papers in the Jurisprudence Department; and The Education of Epileptics, by Dr. L. F. Bryson. (Published by G. P. Putnam's Sons, New York, and Damrell & Upham, Boston.)

In planning his *First Course in Science*, the author, *John F. Woodhull*, believing that the study of text-books alone can not be classed as work in science, and that illustrative or object teaching can be so classed only in part, has attempted to devise means by which apparatus could be put into the hands of each pupil as early as possible. A text-book, however, is essential, and it is given here in two separate but mutually dependent volumes. One volume contains directions to pupils for performing their experiments, sufficient to prevent aimless work, and yet not so full as to interfere with the inductive method. The other volume, the Text-book, is similar to the ordinary text-book, telling how the experiments should result, giving the pupil a correct form of statement for the conclusions and laws which he has learned in a practical way, and furnishing other information. The experiments are on light. On every right-hand page in the Book of Experiments is left a space for the insertion of the pupil's own notes. (Published by Henry Holt & Co., New York. Price of the parts, 50 cents and 65 cents.)

Prof. *Max Müller*, replying to an accusation that his book on the *Science of Thought* was thoroughly revolutionary and opposed to all recognized authorities in philosophy, describes it as rather evolutionary, the outcome of that philosophical and historical study of language which began with Leibnitz and has now spread and ramified so as to overshadow nearly all sciences. The fundamental principle of the book is that language and thought are identical, and one can not be without the other. The three lectures on the subject published by the Open Court Publishing Company, Chicago, are regarded by the author as a kind of preface or introduction to the larger work. To these lectures are added in an appendix the correspondence between Prof. Müller and Francis Galton, the Duke of Argyll, George J. Romanes, and others, on Thought without Words. The lectures are sold, bound in paper, for 25 cents.

The papers in the fourth number of Volume II of the *Bulletin from the Laboratories of Natural History of the State University of Iowa* are technical. Mr. B. Shimek's account of A Botanical Expedition to Nicaragua has a few features of general interest, but the author's mind was too singly fixed upon his collections to permit him to enlarge upon them. Of the other papers, four are upon the slime-molds and other fungi of Nicaragua, Central America, eastern Iowa, and Colorado; two relate to the physiology of the Coleoptera; two, by F. S. Aby, relate to the physiology of the Domestic Cat, and to observations on a case of Leucæmia; and A New Cycad is described by Thomas H. McBride. (Iowa City, Iowa. Price, 50 cents.)

The work described in the *Report of the Botanical Department of the New Jersey Agricultural College Experiment Station for 1892*

relates chiefly to fungous diseases of plants and to weeds. One of the leading diseases investigated has been a serious trouble among beans, producing brown irregular pits on the pods and seeds. This was shown to be due to bacteria. Much attention has been given to fruit diseases and rose troubles; diseases of the violet, nasturtium, and sedum have been studied also. Under the study of weeds the root system has been an objective point. The great size attained by tap roots of some weeds, and the wide extent over which other species may spread under ground, have been shown. The manner in which weeds pass the winter and their agency in propagating fungi have also been looked into.

A thoroughly practical address on *Heating and Ventilation of Residences*, delivered by *James R. Willett* to the engineering societies of the University of Illinois, has been printed by the author. Three modes of heating—by hot water, steam, and hot air—are described in it. Mr. Willett tells how to estimate the amount of radiating surface or the sectional area of hot-air pipes required for a house, how to determine the grate area, the sizes of fittings, and the proper location for all parts of a heating apparatus. There are sixteen plates showing plans and elevations of heating apparatus in houses. Further information is given in tables and in cuts in the text.

In the belief that spelling would be learned incidentally from language lessons, the set study of this subject has been largely discontinued. This belief has proved erroneous in many cases, and a return to the old practice is being made. The renewed demand for spelling books has led to the publication of *The Limited Speller*, by *Henry R. Sanford*, Ph. D. (Bardeen, 35 cents), designed to include all the words in common use which are frequently misspelled. The words are arranged in one alphabetical list, the accent is always marked, and the pronunciation is indicated wherever necessary by diacritics or respelling.

With its number for December, 1893, *New Occasions* began its second volume in a new form and with more pages (Charles H. Kerr & Co., $1 a year). It is edited by *B. F. Underwood*, and is devoted to social and industrial progress. The enlarged size was made necessary by an arrangement to print in the magazine the lectures of the Brooklyn Ethical Association for the past winter. The December number contains the first of these lectures, on Cosmic Evolution as related to Ethics, by Lewis G. Janes. Dr. Janes asks the question, "Can an ethical science be formulated in harmony with cosmic law sufficiently rational and broad to command the allegiance of all liberal-minded people?" and gives some considerations in favor of an affirmative answer. Other topics treated in this number of the magazine are the pardon system, immigration as affected by the tariff, the Eliot-Lewes marriage, and there are briefer articles under the general head of Occasions and Duties.

Many persons are looking to science for some kind of substitute for religion, and several attempts have been made to satisfy this expectation. Among the latest of these is that made by Dr. *Paul Carus* and embodied in *The Religion of Science* (Open Court Publishing Co., 25 and 50 cents). The author's system imitates the form of traditional religion quite closely, while rejecting revelation and anthropomorphism. The religion of science, he says, accepts "Entheism," and he defines this as "the view that regards God as inseparable from the world. He is the eternal in Nature." The authority for conduct in his plan is the system of laws of the universe. Its ethics is the ethics of duty. Its conviction as to immortality is that the soul persists—not as an individual existence—but that it becomes merged in the "soul of mankind." Further resemblances and differences between the new doctrine and the old are set forth in chapters on Mythology and Religion; Christ and the Christians, a Contrast; and The Catholicity of the Religious Spirit.

The *Annual Report of the Chief of Engineers, United States Army, 1893, Part I*, is occupied mainly with accounts of improvements in rivers and harbors on which work was done in the year ending June 30, 1893. Operations were carried on at many places along the Atlantic coast and the Gulf of Mexico, from the St. Croix River in Maine to the harbor at Brazos Santiago, Texas. The Western rivers, the lake harbors and rivers, and the Pacific coast also received considerable attention. Other work done by the engineer corps concerned the bridging of

navigable waters of the United States, public works in the District of Columbia and the Yellowstone National Park, etc.

An essay on the *History of the Philosophy of Pedagogics*, by *Charles W. Bennett*, LL. D., has been published in book form (Bardeen, 50 cents). It sketches the attempts that have been made during the past four or five centuries to base education upon some one principle. The educational work of the religious reformers, abstract theological education, Jesuitism, Jansenism, pietism, realism, humanism, and deism are passed in review, and freedom of activity is described as the final stage. Portraits of leaders of educational thought, from Erasmus to Froebel, are inserted in the text.

In *The Educational Labors of Henry Barnard*, by *Will S. Monroe* (Bardeen, 50 cents), have been chronicled a series of efforts for the uplifting and advancement of education that have seldom been equaled in value. State Superintendent of Education in Connecticut from 1838 to 1842 and 1851 to 1855, holding the same office in Rhode Island from 1842 to 1849, President of the University of Wisconsin, and later of St. John's College at Annapolis, and United States Commissioner of Education from 1867 to 1870, Mr. Barnard has had many and important fields of usefulness. In 1855 he founded the American Journal of Education, of which thirty-one volumes have been issued. Four portraits of Mr. Barnard and a bibliography of his writings are included in the volume.

PUBLICATIONS RECEIVED.

Adler, Hermann, M. D. Alternating Generations. A Biological Study of Oak Galls and Gall Flies. Translated and edited by Charles R. Stratton. New York: Macmillan & Co. Pp. 198, with Plates. $3.25.

Agricultural Experiment Stations. Bulletins and Reports. Connecticut: Seventeenth Annual Report. Pp. 331.—Babcock Test for Cream. Pp. 240.—Michigan: Fruit Bulletins. Pp. 135.—Bulletins 107 to 110. Lambs, Potatoes, Vegetables, and the Horse. Pp. 100.—Storrs, Conn.: Sixth Annual Report. Pp. 200.

Carnegie, Douglas. Law and Theory in Chemistry. New York: Longmans, Green & Co. Pp. 222. $1.50.

Cline, I. M. Climate and Health of Galveston, Texas. Pp. 7.—Summer Hot Winds on the Great Plains. Pp. 40.

Correspondence School of Technology. Cleveland, Ohio. Catalogue. Pp. 23.

Cragin, Prof. F. W., Colorado Springs, Col. Vertebrata from the Neocomian of Kansas. Pp. 4.—New and Little-known Invertebrata from the Neocomian of Kansas. Pp. 12.

Ewing, J. A. The Steam Engine and other Heat Engines. New York: Macmillan & Co. Pp. 400. $3.75.

Fewkes, J. Walter, Boston. Dolls of the Tusayan Indians. Leiden. Pp. 30, with Plates.

Foley, William C. Armor Protection for Heavy Guns in Battle Ships. Pp. 12.

Hague, Arnold. The Yellowstone Park. Pp. 24.—The Great Plains of the North. Pp. 6.

Harris, W. T. Report of the Commissioner of Education for 1890–'91. Two Volumes. Pp. 1549.

Holt, L. Emmett. The Care and Feeding of Children. New York: D. Appleton & Co. Pp. 65. 50 cents.

Huxley, T. H. Man's Place in Nature. New York: D. Appleton & Co. Pp. 328. $1.25.

Keen, W. W., M. D. Ligation of the Common and External Carotid Arteries and the Jugular Vein. Pp. 3.—Operation Wounds of the Thoracic Duct in the Neck. Pp. 10.—Removal of the Gasserian Ganglion for Tic Douloureux. Pp. 14.—Oval Hæmorrhoid: Operation and Cure. Pp. 4.

Lewis, the late Henry Carvill. Papers and Notes on the Glacial Geology of Great Britain and Ireland. Edited from his unpublished manuscripts, with an Introduction by Henry W. Crosskey. New York: Longmans, Green & Co. Pp. 469.

Lockwood, Jean Boag, General Manager. The Epitome. Monthly. May, 1894. Vol. I, No. 1. Pp. 64. 20 cents, $2 a year.

Lonsdale, E. H. Southern Extension of the Cretaceous in Iowa. Pp. 10.

Marine Biological Laboratory. Sixth Annual Report for the Year 1893. Boston. Pp. 46.

Marshall, the late Arthur Milnes. Biological Lectures and Addresses. New York: Macmillan & Co. Pp. 366.

Mason, Otis T. The Birth of Invention. Pp. 12.—The Progress of Anthropology in 1892. Pp. 48. Technogeography, or the Relation of the Earth to the Industries of Mankind. Pp. 24.

Missouri. Twenty-fifth Annual Report of the Superintendent of the Insurance Department. Pp. 28.

"Ormond." Suggestive Essays on Various Subjects. Creation *vs.* Evolution. Chicago: The Blakely Printing Company. Pp. 67.

Palmer, Julius A. About Mushrooms. Boston: Lee & Shepard. Pp. 100. $2.

Powell, J. W., Director. Twelfth Annual Report of the United States Geological Survey. Two Volumes. Pp. 675 and 576, with Maps and Plates.

Shufeldt, R. W., M. D. Comparative Oölogy of North American Birds. Pp. 32.—Scientific Taxidermy for Museums. Pp. 72.

Silberstein, Solomon. Six General Laws of Nature. New York. Pp. 49.

Slater, John F. Fund for the Education of Freedmen. Proceedings of the Trustees. Pp. 42.

Smithsonian Institution. List of Publications for Sale or Exchange. Pp. 26.

Spratt, Leonidas, Jacksonville, Fla. Man in Continuation at this Earth of a Nature of Reality throughout the Universe. Pp. 109.

Stewart, D. D., M. D. Tests for Serum Albumen in the Urine. Pp. 19.—Non-albuminous Nephritis. Pp. 27.

Stokes, Anson Phelps. Joint-Metallism. New York: G. P. Putnam's Sons. Pp. 124.

Thompson, A. H. The Origin and Evolution of the Human Face and the Descent of Facial Expression. Pp. 20.

Trelease, William, St. Louis. Leitneria Floridana. Pp. 26, with 14 Plates.

University of the State of New York. Secretary's Report. Albany. Pp. 324. 35 cents.

Ward, H. Marshall. Action of Light on Bacteria and Fungi. Pp. 21.

Ward, Lester F., Washington. The Cretaceous Rim of the Black Hills. Pp. 16.—Neo-Darwinism and Neo-Lamarckism. Pp. 71.—Principes et Méthodes d'Étude de Corrélation géologique au Moyen des Plantes fossiles (Methods of Study of Geological Correlation by Means of Fossil Plants). Pp. 10.

"Wheelbarrow." Articles and Discussions on the Labor Question. Pp. 303. $1.

Wilkins, W. H., and Vivian, Herbert. The Green Bay Tree. New York: J. Selwin Tait & Sons. Pp. 389. 50 cents.

Wright, Mabel Osgood. The Friendship of Nature. Pp. 238. 75 cents.

POPULAR MISCELLANY.

Prof. William Dwight Whitney.—Prof. William Dwight Whitney, of Yale College, the foremost and greatest American philologist, died June 7th, in the sixty-eighth year of his age. He was born at Northampton, Mass., in 1827; was graduated from Williams College in 1845; after spending three years in the Northampton Bank, he went to Lake Superior in 1849 as an assistant in botany and ornithology in the United States Geological Survey. Having begun the study of Sanskrit, he continued it at Yale College, under Prof. Salisbury, for one year after his return from this work. He then studied in Germany, under Prof. Weber, of Berlin, and Prof. Roth, of Tübingen. Before he was thirty years of age he had edited, with Prof. Roth, the Atharda Veda, and had become Professor of Sanskrit in Yale College. He prepared a series of German text-books which have sustained an excellent reputation, and continued the publication of Sanskrit books in rapid succession, crowning the series with a Sanskrit grammar in English and German, and a book on the Roots, Verb Forms, and Primary Derivatives of the Sanskrit Language, which appeared in 1879. These works, says the Nation, "are based, not on the dicta of predecessors, but upon actual observation of the facts of the language, which are subjected to masterly classification and vigorously scientific induction." He wrote frequent and valuable essays on Hindu astronomy, phonetics, comparative grammar, and mythology; Oriental religions and literature, and the origin and nature of languages; and delivered lectures at the Smithsonian and Lowell Institutions, out of which grew the volume on the Life and Growth of Language of the International Scientific Series and his book on Language and the Study of Language, which have been widely translated. Other essays were embodied in the book, Oriental and Linguistic Studies. He was an important contributor to the Sanskrit-German Lexicon published by the Imperial Academy of Russia, 1852–'75; was a member and officer of the American Oriental Society for fifty-one years, and its president after 1884; was first president of the American Philological Association and a frequent contributor to its Transactions and Proceedings; was editor-in-chief of the Century Dictionary, and was a member of numerous learned societies abroad. A biographical sketch of Prof. Whitney was given, with portrait, in The Popular Science Monthly for May, 1879 (Vol. XV).

Women and Education in the South.—A valuable circular published by the United States Bureau of Education is that on Southern Women in the Recent Educational Movement in the South, which has been prepared by the Rev. A. D. Mayo, and embodies a review of what he has seen and learned during twelve years that he has been engaged in the service of education in the South, in which he has come in contact with every variety of school, both races, and all classes. The essay presents three main divisions, relating respectively to Southern schools for the education of girls; the work of Northern and Southern women in the superior schools for colored youth; and the common school; in all of which departments the women of the South are becoming every year more broadly and vitally interested. To the principal paper are added in an appendix several essays, originally presented as lectures or magazine articles, bearing on the subject of education in the South.

Cause of the Migration of Birds.—Concerning the reason of birds migrating, Canon Tristram observed in the British Association that observation has brought to light many facts which seem to increase the difficulties of a satisfactory answer to the question. The autumnal retreat from the breeding quarters might be explained by a want of sufficient sustenance as winter approaches in the higher latitudes, but this will not account for the return migration in spring, since there is no perceptible diminution of

supplies in the winter quarters. The northward movement of all the others must be through some impulse not yet ascertained. In many other instances it is not dependent on the weather at the moment. This is especially the case with sea birds. Prof. Newton observes they can be trusted as the almanac itself. Foul weather or fair, heat or cold, the puffins—*Fratercula arctica*—repair to some of their stations punctually on a given day, as if their movements were regulated by clockwork. In like manner, whether the summer be cold or hot, the swifts leave their summer home in England about the first week in August, only occasional stragglers ever being seen after that date. To say that migration is performed by instinct is no explanation of the marvellous faculty; it is an evasion of the difficulty. The sense of sight can not guide birds which travel by night, or span oceans or continents in a single flight. In noticing all the phenomena of migration there yet remains a vast untilled region for the field naturalist. What Prof. Newton terms the sense of direction, unconsciously exercised, is the nearest approach yet made to a solution of the problem. He remarks how vastly the sense of direction varies in human beings, contrasting its absence in the dwellers in towns compared with the power of the shepherd and the countryman, and, infinitely more, with the power of the savage or the Arab.

Chemical Constitution and Color.—A curious side light, says Prof. James Emerson Reynolds, seems to be thrown on the nature of the elements by the chemico-physical discussion of the connection existing between the constitution of certain organic compounds and the colors they exhibit. We may take it as an established fact that a relation exists between the power which a dissolved chemical compound possesses of producing the color impression within our comparatively small visual range, and the particular mode of grouping of its constituent radicals in its molecule. Further, the reality of this connection will be most freely admitted in the class of aromatic compounds—that is, in derivatives of benzene, whose constituents are so closely linked together as to exhibit *quasi*-elemental persistence. If, then, the possession of what we call color by a compound be connected with its constitution, may we not infer that "elements" which exhibit distinct color, such as gold and copper, in thin layers and in their soluble compounds, are at least complexes analogous to definitely decomposable substances? This inference, while legitimate as it stands, would obviously acquire strength if we could show that anything like isomerism exists among the elements; for identity of atomic weight of any two chemically distinct elements must, by all analogy with compounds, imply dissimilarity in constitution, and therefore definite structure, independently of any argument derived from color. Now, nickel and cobalt are perfectly distinct elements, as we all know, but, so far as existing evidence goes, the observed differences in their atomic weights (nickel, 58·6; cobalt, 58·7) are so small as to be within the range of the experimental errors to which the determinations were liable. Here, then, we seem to have the required example of something like isomerism among elements, and consequently some evidence that these substances are complexes of different orders; but in the cases of cobalt and nickel we also know that in transparent solutions of their salts, if not in thin layers of the metals themselves, they exhibit strong and distinct colors—compare the beautiful rosy tint of cobalt sulphate with the brilliant green of the corresponding salt of nickel. Therefore, in exhibiting characteristically different colors, these substances afford us some further evidence of structural differences between the matter of which they consist, and support the conclusion to which their apparent identity in atomic weight would lead us. By means of such side lights we may gradually acquire some idea of the nature of the elements, even if we are unable to get any clew to their origin other than such as may be found in Crookes's interesting speculations.

The Camphor Tree.—While camphor was formerly produced in Sumatra, Borneo, and other parts of the East Indies, all now known to the trade comes from Japan and Formosa. The camphor tree is a large evergreen of symmetrical proportions, somewhat resembling a linden. It bears a white flower which ripens into a red berry. Some of the

trees are fifteen feet in diameter and live to a great age. A group of trees in the province of Toosa, about a century old, are estimated to be equivalent to about forty thousand pounds of crude camphor. The camphor is extracted from chips taken from the roots or from the stem near the root, the wood yielding about five per cent of camphor, and the root a larger proportion. The annual export of Japan camphor averages about five million pounds. The forests in Japan owned by the people are now almost denuded of timber, but the Government still possesses large woods of camphor trees, which, it is estimated, will maintain a full average supply of the gum for the next twenty-five years. Plantations of young trees are also making and well taken care of; and although camphor has not hitherto been extracted from trees less than seventy or eighty years old, it is expected that under the present intelligent management equally good results may be realized in twenty-five or thirty years. The Japanese Department of Forests, which has the control of these woods, is under good management.

Constitution of the Ether.—Assuming that the elastic solid theory of the ether has failed, Mr. R. T. Glazebrook thinks that the properties of the ether which would lead to the equations that represent the laws of the transmission of light, may be found in the labile ether of Lord Kelvin. This is an elastic solid, or *quasi* solid incapable of transmitting normal waves. Such a medium would collapse unless of infinite extent, or else fixed at its boundaries. A soap bubble affords in two dimensions an illustration of it, the tension being independent of its dimensions. Waves of displacement parallel to the surface of the film would not be transmitted. But such a film in consequence of its tension has an apparent rigidity for displacements normal to its surface; it can transmit transverse waves with a velocity which depends on the tension. Now the labile ether is a medium which has, in three dimensions, characteristics resembling those of the two dimensional film. Given such a medium—and there is nothing impossible in its conception—and the main phenomena of light follow as a necessary consequence. Lord Kelvin, again, has shown us how such a medium might be made up of molecules, having rotation in such a way that it could not be distinguished from an ordinary fluid in respect to any rotational motion; it would, however, resist rotational movements with a force proportional to the twist, just the force required. The medium has no real rigidity, but only a *quasi* rigidity conferred on it by its rotational motion. The actual periodic displacements of such a medium may constitute light. We may claim, then, with some confidence, to have a mechanical theory of light. But nowadays the ether has other functions to perform, and there is another theory to consider, which at present holds the field. Maxwell's equations of the electro-magnetic field are practically identical with those of the *quasi*-labile ether. The symbols which occur can have an electromagnetic meaning; we speak of permeability and inductive capacity instead of rigidity and density, and take as our variables the electric or magnetic displacements instead of the actual displacement of the rotation. Still, such a thing is not mechanical, and we have no satisfactory mechanical theory of the electro-magnetic field. But the theory of the *quasi*-labile ether may be applied, and gives two analogies according as we regard the density of the medium to be analogous to electrostatic inductive capacity or to magnetic permeability.

Explorations in Thibet.—In a paper on Recent Explorations in Thibet, Mr. E. Delmar Morgan said in the British Association that the discoveries made by travelers, beginning with the Schlagintweit brothers and ending with Dr. Thorold's recent journey, had opened out new fields of research in hitherto inaccessible parts. They had determined the continuity of the Kuen Luen mountain system through twenty degrees of longitude, and made known the direction and structure of the principal chains. They had shown the lacustrine character of the central plateaus, and traced almost to their sources some of the mightiest rivers of Asia. They had thrown light on the climatic conditions of these lofty deserts, and seen an abundance of animal life on them. Their researches had proved the existence, in former times, of a line of flourishing oases along the northern foot of the Kuen Luen,

by which the Chinese silk trade passed in the middle ages, and had brought to light the leading gold fields of northern Thibet.

Weather and the Mind.—The psychology of the weather is suggested by Dr. T. D. Crothers as a promising subject for study. He says, in Science: "Very few persons recognize the sources of error that come directly from atmospheric conditions on experimenters and observers and others. In my own case I have been amazed at the faulty deductions and misconceptions which were made in damp, foggy weather, or on days in which the air was charged with electricity and thunderstorms were impending. What seemed clear to me at these times appeared later to be filled with error. An actuary in a large insurance company is obliged to stop work at such times, finding that he makes so many mistakes which he is only conscious of later that his work is useless. In a large factory from ten to twenty per cent less work is brought out on damp days and days of threatening storm. The superintendent, in receiving orders to be delivered at a certain time, takes this factor into calculation. There is a theory among many persons in the fire-insurance business that in states of depressing atmosphere greater carelessness exists and more fires follow. Engineers of railway locomotives have some curious theories of trouble, accidents, and increased dangers in such periods, attributing them to the machinery." Dr. Crothers adds that the conviction prevails among many active brain workers in his circle that some very powerful forces coming from what is popularly called the weather control the work and its success of each one.

Seeking Perfection.—The Rev. J. A. Wylie, describing his journey through central Manchuria, speaks of a charming place, the Lao Te Ling, near Ta Shin Ho, where, at the summit of a hill, "there are several fine temples, including one, a large Buddhist temple, in course of erection; and in connection with this there is an interesting story. In a little house with eight feet by six feet of accommodation, two thirds of which is occupied by a small Kang, there lives a Buddhist priest. His head is not close-shaven, as the heads of other Buddhist priests are, for since taking up his residence in these quarters, or rather in this sentry box, he has allowed his locks to grow. For four years has he already been here, and another three years at least remain for him to stay. He is seeking to attain perfection, and he must finish what he has begun. Not until the temple is finished building will he be at liberty to leave his post. The little door of this priest's domicile is sealed up, so he never even steps out into the open air; there is only a small opening in the door or window for an attendant to hand in his meals. These meals are scanty and few; only one meal a day at noon. He drinks great quantities of tea, however; he seems to put no limit to his indulgence in that beverage. In sleep he does not stretch himself out; in fact, he never lies down, he only half reclines, and, asleep or awake, he constantly keeps pulling away at a rope which connects with the temple bell, which must never cease to ring. Travelers passing at all hours may hear the bell sounding; this is part of his work of merit. While I was with him, even although we spoke in such a way that everything else might be forgotten, he did not forget to pull the rope. How, during sleep, he manages is to me the mystery. He had heard long ago of the Christian religion; some books I offered him he refused, on the ground that before he had purified himself by completing his task it would be sacrilege to touch these books. When I pressed him he accepted them, however. How earnest must this man be when he thus denies himself! Still it is merit, and merit for himself, that he is endeavoring to attain."

Coal-dust Explosions.—A strong confirmation of the theory that coal dust is a frequent cause of explosions in coal mines is given by the experiments made in the White Moss Colliery, Skelmersdale, and recorded by Mr. Henry Hall, inspector of mines. It appears from them that the flame from a blowing-out gunpowder shot in the presence of dry coal dust is always found to ignite more or less such dust and to increase the burning and charring effects of the shot. When a large flame, such as that of a blowing-out gunpowder shot, or the flame from the ignition of a small quantity of fire damp,

traverses an atmosphere containing a very moderate quantity of dry coal dust, the dusty atmosphere will explode with great violence, and the explosion will continue and pass throughout any length of such atmosphere, its violence and force increasing as it progresses. The coal dust from several seams in certain different districts is almost as sensitive to explosion as gunpowder itself, the degree of sensitiveness increasing in proportion to its high quality and freedom from impurities. In mines which are briskly ventilated there is a greater probability of explosion, while in such cases it is generally more severe. One of the most important results of the experiments made has been to demonstrate that certain high "explosives" (roburite, ammonite, etc.) are incapable of igniting or exploding coal dust. Mr. Hall, in face of these facts, is therefore led to urge the total abolition of gunpowder from coal mines for blasting purposes and the substitution of certain "high explosives"—precautionary measures which many large firms have already adopted. Apart from the danger of using gunpowder arising from the ease with which it starts a dust explosion, it appears that in mere handling alone four hundred lives have been sacrificed during the last twenty years, while the loss of life from explosions caused by gunpowder during the same time has been at least one half of the total loss —viz., 4,098 persons. With regard to preventive measures, every possible effort, it is recommended, should be made, either by watering the dry dust or removing it to avoid accumulation, so that any accidental ignition of fire damp may be limited in its effects and prevented from developing into a sweeping explosion through the agency of dust.

Birds of Michigan.—The Bird Fauna of Michigan, as described by Mr. A. J. Cook in a bulletin of the State Agricultural Experiment Station, being protected by the Great Lakes nearly surrounding the State, is very interesting. As is shown by Dr. C. Hart Merriam's colored map, it embraces representatives of three distinct faunas—viz., the boreal in the north, which includes the northern peninsula and the northern part of the southern peninsula; the transition, which occupies nearly all the southern peninsula, and reaches slightly into Indiana and Ohio; and the upper Sonoran, which, though mostly to the south of Michigan, reaches into the southeastern and southwestern corners of the State. There are met in Michigan many birds peculiar to the far north, and others that dwell for the most part in the States and countries to the south, even reaching to and beyond the Gulf. The first are illustrated in the Bohemian waxwing, the spruce partridge, the Canada jay, and the pine grosbeak; and the summer redbird, the mocking bird, and the cardinal redbird illustrate the second group. The large lakes attract many birds that are usually maritime, like the gulls and the terns; while in southern Michigan, with its prairies and woodlands, both widely distributed, are found the prairie fauna, as illustrated in the pinnated grouse, and those birds which are most at home in the forests of wooded areas, like most of the thrushes and the warblers.

The Future Work of the American University.—Addressing the Pennsylvania State Board of Agriculture on the Progress and Practical Value of Agricultural Science, Dr. Peter Collier gave a prominent place in illustration to the work that has been done in the analysis of fertilizers, whereby frauds have been exposed, and farmers have been pecuniarily benefited by the cheapening of fertilizing materials and the assurance of increased and improved crops. A further illustration is found in the progress and practical applications of bacteriology—a word which, together with bacteria, does not occur in the standard dictionaries of 1868—by means of which the causes and cures of the most serious maladies that affect crops have been discovered and brought within the reach of all, and such operations as the making of butter and cheese are facilitated. One would not have imagined a short time ago that physics and physiology were the sisters of psychology, or that ethics should consort with economics and sociology in the same laboratory, or that a professor of institutional history should commend to his pupils biology as a minor subject. Yet all these things have really happened. Indeed, only since Darwin and Spencer has it been possible to discover the essential kinship of the various branches of knowledge. Projecting

the future of the American university, the author assumes that it must become the representative of dynamic culture. The university should have much to do with social reforms, political regeneration, and correction of errors in the treatment of criminals. Social and political reform will be impossible without moral regeneration, in which, as the work must begin with the individual, the university has a noble part to perform. "The fact is, the American people need a tonic of the most active kind. Partly as a result of the spoils system and partly in consequence of the unnatural industrial and political conditions produced by the civil war, we have been brought to a very low plane of public morality. 'It is a familiar fact,' says Herbert Spencer, 'that the corporate conscience is ever inferior to the individual conscience.' Indeed, it seems to me that a nation is in evil straits when the standard of public morality is very much lower than the standard of private morality, and that is precisely the case with the people of the United States. Never, perhaps, has there been a greater disparity between political and private ethics. A double system of morality is a dangerous possession for any nation. Our ideal of public conduct must approximate more nearly to our ideal of private conduct if we would ever attain the best in the higher life."

Remaking our Boys.—"Boys, as they are made," as contemplated by F. H. Briggs, of the State Industrial School, Rochester, in an address concerning them, are not the boys who have home privileges and careful, competent home training, but the boys of the slums, and of the poor and the degraded. The question, How to remake them? is one that the public school should have an important part in answering. For the child-boy, in the author's view, the kindergarten should be substituted for the home and street during the day, and one should be established, where all will be treated with equal consideration, in every locality where the poor abound. "The kindergarten gives the child the mental, physical, and moral exercise that it needs. . . . But what about the boys who are beyond the kindergarten age now, and about the boys who have passed through the kindergartens? Put them into manual training schools. . . . What should be the instruction in these schools? That which in a natural way develops the physical, mental, and moral faculties. The workshop should form an inseparable concomitant of every school. Children delight in doing. This is why the kindergarten is so effective as an educational agent." Our school for the boy should have drawing for its corner stone; and modeling should accompany it, that by the test of actual contact the correctness of the perceptions of size and form may be tested, and the love of the beautiful more fully gratified. Then the use of woodworking tools—the one thing that a boy always delights in. "It helps a boy to find out what square means. When he can saw to the line every time, he has a greater respect for truth. When he habitually becomes exact in the use of tools the great battle is won. Your skilled mechanic is not usually a liar. His respect for exactness makes him hard to the line in his speech. These three, then, drawing, modeling, and woodworking in its various forms, should form the foundation upon which our remaking structure should rest." And they should add development and symmetry to the whole. "These things lie at the very basis of all handicraft. They enable one trained in them to see things in new ways; to see their parts, their forms, their beauties; in fact, as training for the perceptive and conceptive faculties they have no equal. No scheme of education is complete that leaves music out." Nature has a warm place in every child's heart. It is ever presenting some new form for contemplation; "and as bud, leaf, flower, and fruit appear they challenge the child's attention and invite study. . . . Why has Nature been so long a closed book to the masses? Why is so much that is beautiful and ennobling denied to the famishing souls of little children? Why should natural history and science wait for the high-school or college course that the great mass of people never reach?"

Town Refuse as Fuel.—Experiments in seeking to utilize the refuse of towns as fuel have been carried so far that a plant, known as the Livèt plant, has been set up in Halifax, England, with which it is intended to supply electric energy. The successful

working of the Livèt furnace appears to depend upon the peculiar construction of its flues, which are so built as to utilize the effect of the decreasing volume of the gases of combustion traveling toward the chimney, so promoting a high velocity to the air passing through the furnace bars and producing rapid combustion with intense heat. At the same time, the effect of this peculiarity of construction is to cause the gases themselves to move slowly through the flues, so that they may part with their useful heat before escaping into the atmosphere. The force of draught at the furnace is such that a high and constant temperature is obtained and efficiency of combustion insured, while all unpleasant odors inherent in town garbage are destroyed. As an example of the heat economy effected, it is said that whereas in previous generators the best results ever obtained have been three quarters of a pound of water evaporated on the combustion of one pound of refuse, in the Livèt generator over three pounds of water are evaporated into steam for every pound of refuse consumed, in spite of the fact that it is frequently known to contain twenty per cent of moisture. The temperature of the gases just before entering the chimney is stated to be from 300° to 400° Fahr. lower than hitherto obtained. The progression of the gases is partially arrested at both ends of each flue for the purpose of permitting them to deposit the contained light dust in suitable expansion chambers or pits which can be cleaned out when desirable. This arrangement serves to overcome the objectionable dust, which in ordinary "destructors" tends to choke the flues and impregnate the air of the surrounding districts.

Uses of Drinks.—In discussing the question whether Australia will become a wine-drinking country, Dr. Murray Gibbs pointed out that different nations had always, from time immemorial, selected certain beverages as national drinks, and that the fact that the fruit, leaf, or grain supplying the essential principle of the drink was not always indigenous to the national soil was itself a proof that convenience was not the only factor indicating the choice. Many continental nations drink, of course, the wine of their particular district, and for centuries the Englishman's beer was made from the Englishman's barley. On the other hand, the universal vogue of drinking decoctions made from the Eastern shrubs tea and coffee shows that the popularity of a beverage has no geographical limits. The character of the drink adopted as national must always be largely dictated by the character of the soil and food, and this, in turn, is dependent upon the climate of the country. Sir William Roberts has said that all beverages, alcoholic or non-alcoholic, conduce to one of two conditions—retardation of the digestive process or excitation of the nervous system. The harsher climates require the stronger foods, and these—inasmuch as time is necessary for their proper assimilation—call for checks upon a too rapid and so incomplete digestion. Chief among these are the vegetable acids contained in wine, and the sedative properties of tea and coffee.

Occupations to awaken Dormant Faculties.—In a paper on Industrial Training in Reformatory Institutions (published by C. W. Bardeen, Syracuse, N. Y.) Mr. F. M. Briggs, of the State Industrial School, relates a few incidents of cases in which mental powers, before dormant, were awakened by setting pupils at work for which they had a taste. "There are boys in the State Industrial School at the present time," the author says, "whose interest we could not arouse in the common schools. Some were naturally so weak mentally that, after weeks of conscientious work on the part of the teacher, they were not able to repeat from memory a four-verse stanza of a poem for children. Others would not apply themselves sufficiently long to learn anything. Some of these boys were placed in the clay-modeling and wood-carving shop. The boys who had been regarded as almost idiots soon began to show improvement. The boys who had been especially troublesome elsewhere, in the clay work ceased to be annoying. When a boy begins work with clay, he seems to feel himself in the unity of things and he becomes happy accordingly; and, as he sees the formless clay take shape beneath his touch, a sense of power is born within him which arouses and quickens him." A boy who had been cruel, cunning, and vicious, presenting no point for reaching his nature, one day in the wood-working shop

asked his teacher to look at a molding board he had made. "The old spirit seemed to be gone as he showed me the result of his handiwork; unconsciously he had found the secret of power." Another boy, regarded as hardly more than an idiot, had been gaining in his shop work, with his eye taking new brightness and his face clearing; and his school work showed the effect of the shop training. Another boy, a persistent offender in shop and school, expressed a desire, when decorating was introduced, to do work of that kind. The request was granted, and "his first effort showed his ability, and a new manhood asserted itself within him."

Beginnings of Mountain Climbing.—The glaciers of the Alps began to attract the attention of scientific men toward the end of the seventeenth century, but travelers making the grand tour considered mountains hideous. It was not, says Mr. W. M. Conway, till the dawn of romanticism, a hundred years later, that the beauty of mountains began to be recognized. The first snow mountains to be climbed were the Titlis in 1739. Pococke and Windham's visit to the Chamounix followed in 1741, and with that the modern epoch of Alpine exploration may be said to have begun. In 1775 an attempt was made to reach the summit of Mont Blanc. This was repeated in several subsequent years, till in 1786 Jacques Balmat and Michel Paccard were successful. De Saussure's famous ascent was made in 1787. During the next half century the prejudice against mountains and dread of them were gradually dissolved. The Jungfrau was climbed in 1811, the Finsteraarhorn in 1812, and other peaks followed. It was not till after 1850 that systematic Alpine climbing could be said to have been introduced. The present Mr. Justice Willis's ascent of the Wetterhorn in 1854 was usually recognized as the first important "sporting" climb. From that time forward the exploration of the Alps advanced rapidly. Monte Rosa was climbed in 1855, Mont Blanc without guides and by a new road in 1856. In 1859 the Alpine Club was founded in London, and the example thus set was shortly afterward followed by foreign mountaineers. Thenceforward the exploration of the Alps advanced rapidly, and it might now be regarded as fairly complete, so far as the main groups are concerned.

NOTES.

THE summer meeting of the Northwestern Electrical Association was to be held in St. Paul, Minn., July 18th, 19th, and 20th. A larger number of attendants was expected than were present at the last meeting, including representatives from Illinois, Iowa, Michigan, Wisconsin, and North and South Dakota. An excellent programme was prepared, and speakers were invited from among the most expert representatives of the profession.

THE essential oils were held in high esteem by the ancients, but lately seem to have been forgotten in the multitude of new discoveries. The power of many of them to destroy bacteria has, however, been demonstrated anew by M. Chamberland, M. Cadéac, and M. Meunier, and M. Blaizot and M. Caldagues have found in them bactericidal powers even greater than they had been supposed to possess. The essences found by these gentlemen to be most active are those of cinnamon, lavender, marjoram, cloves, geranium, vervain, and tuberose. The simple exposition of their vapors is sufficient to destroy in an hour such microbes as those of pus and cholera, and six minutes' exposure effects a manifest attenuation of their activity.

THE method of purification by distillation in a vacuum, which has hitherto been little employed, except with mercury, has been applied by Prof. G. W. Kahlbaum, of Basle, with great success to potassium, sodium, selenium, tellurium, cadmium, magnesium, bismuth, and thallium, while the experiments with zinc and manganese have so far been unsatisfactory. Judging by spectrum analysis, an extreme degree of purity was obtained. Thus, thirty-five lines disappeared from the spectrum of tellurium, showing, the author believes, the absence of substances which modify the spectrum of the purest metal obtainable by other processes.

Two living German princes have distinguished themselves by becoming practicing physicians—Duke Karl Theodor, of the royal house of Bavaria, having completed a course of study, has made a specialty of eye diseases as they occur among the poor, and in April, 1893, successfully performed his two thousandth operation for cataract. Prince Louis Ferdinand, his cousin, besides being engaged in practice, works in the laboratory, and has recently made the etiology and pathology of pleurisy objects of special clinical and bacteriological studies. He has lately published a monograph concerning twenty-three patients suffering from pleuritis who came under his observation.